



US009419483B2

(12) **United States Patent**
Hunstable

(10) **Patent No.:** **US 9,419,483 B2**
(45) **Date of Patent:** **Aug. 16, 2016**

(54) **DC ELECTRIC MOTOR/GENERATOR WITH
ENHANCED PERMANENT MAGNET FLUX
DENSITIES**

USPC 310/156.38, 156.43
See application file for complete search history.

(71) Applicant: **Linear Labs, Inc.**, Granbury, TX (US)

(72) Inventor: **Fred E. Hunstable**, Granbury, TX (US)

(73) Assignee: **Linear Labs, Inc.**, Granbury, TX (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 567 days.

(21) Appl. No.: **13/848,048**

(22) Filed: **Mar. 20, 2013**

(65) **Prior Publication Data**

US 2013/0249343 A1 Sep. 26, 2013

Related U.S. Application Data

(60) Provisional application No. 61/613,022, filed on Mar.
20, 2012.

(51) **Int. Cl.**

H02K 1/17 (2006.01)
H02K 1/27 (2006.01)
H02K 3/04 (2006.01)
H02K 1/30 (2006.01)
H02K 31/02 (2006.01)

(52) **U.S. Cl.**

CPC .. **H02K 3/04** (2013.01); **H02K 1/17** (2013.01);
H02K 1/2766 (2013.01); **H02K 1/30** (2013.01);
H02K 31/02 (2013.01)

(58) **Field of Classification Search**

CPC H02K 1/12; H02K 1/14; H02K 1/17;
H02K 1/27; H02K 1/30; H02K 3/04; H02K
21/12; H02K 21/22; H02K 21/24

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,703,370	A	3/1955	Steensen	
3,300,663	A	1/1967	Rosaen	
3,895,245	A	7/1975	Bode	
4,237,396	A	12/1980	Blenkinsop	
4,388,547	A *	6/1983	Gruber	310/266
4,629,921	A	12/1986	Gavaletz	
5,594,289	A	1/1997	Minato	
5,886,450	A	3/1999	Kuehnle	
6,104,108	A	8/2000	Hazelton	
6,388,352	B1	5/2002	Huang	

(Continued)

FOREIGN PATENT DOCUMENTS

JP	S61173658	A	8/1986
JP	2002369473	A	12/2002
KR	101276633	B1	6/2013

OTHER PUBLICATIONS

International Search Report and Written Opinion of the International
Searching Authority from PCT/US2013/033198, dated Aug. 8, 2014,
8 pages.

(Continued)

Primary Examiner — Tran Nguyen

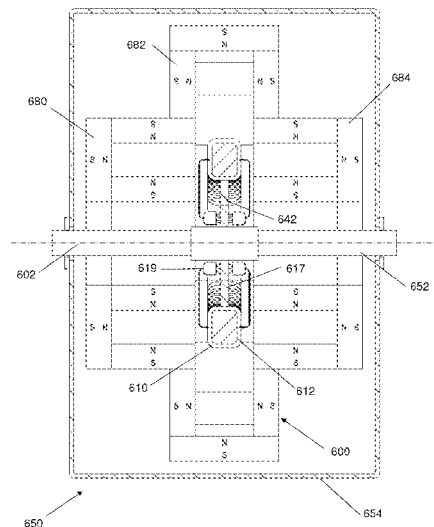
(74) Attorney, Agent, or Firm — Bill R. Naifeh

(57)

ABSTRACT

This disclosure relates in general to a new and improved
electric motor/generator, and in particular to an improved
system and method for producing rotary motion from a elec-
tro-magnetic motor or generating electrical power from a
rotary motion input by concentrating magnetic forces due to
electromagnetism or geometric configurations.

3 Claims, 21 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

6,531,799	B1	3/2003	Miller	
6,664,704	B2	12/2003	Calley	
6,806,607	B2	10/2004	Lau	
6,891,299	B2	5/2005	Coupart	
6,924,574	B2	8/2005	Qu et al.	
6,924,579	B2	8/2005	Calley	
6,930,421	B2	8/2005	Wise	
6,967,424	B2	11/2005	Popov	
6,979,925	B2	12/2005	Schwamm	
7,233,088	B2	6/2007	Wise	
7,279,818	B1	10/2007	Wise	
7,315,103	B2	1/2008	Qu	
7,554,241	B2 *	6/2009	Rao	310/266
7,755,244	B2 *	7/2010	Ley et al.	310/216.019
7,765,905	B2	8/2010	Trumper	
8,008,821	B2	8/2011	Calley	
8,063,528	B2	11/2011	Toot	
8,362,731	B2	1/2013	Smith	
8,400,037	B2	3/2013	Wojtowicz	
8,415,848	B2	4/2013	Calley	
8,598,754	B2	12/2013	Lacour	

2003/0025417	A1 *	2/2003	Rose	310/180
2004/0027022	A1	2/2004	Weir	
2004/0194286	A1	10/2004	Rose	
2008/0278019	A1	11/2008	Lu et al.	
2009/0224628	A1	9/2009	Hiwaki et al.	
2009/0261675	A1	10/2009	Hsiao et al.	
2011/0187222	A1	8/2011	Li et al.	

OTHER PUBLICATIONS

Aydin, Metin, et al., "Design and 3D Electromagnetic Field Analysis of Non-slotted and Slotted TORUS Type Axial Flux Surface Mounted Permanent Magnet Disc Machines," IEEE International Electric Machines and Drives Conference, Jun. 17-20, 2001, pp. 645-651.

Aydin, Metin, et al., "Performance Evaluation of an Axial Flux Consequent Pole PM Motor Using Finite Element Analysis," IEEE International Electric Machines and Drives Conference, vol. 3, Jun. 1-4, 2003, pp. 1682-1687.

Huang, Surong, et al., "TORUS Concept Machines: Pre-Prototyping Design Assessment for Two Major Topologies," IEEE Industry Applications Conference, vol. 3, Sep. 30-Oct. 4, 2001, pp. 1619-1625.

* cited by examiner

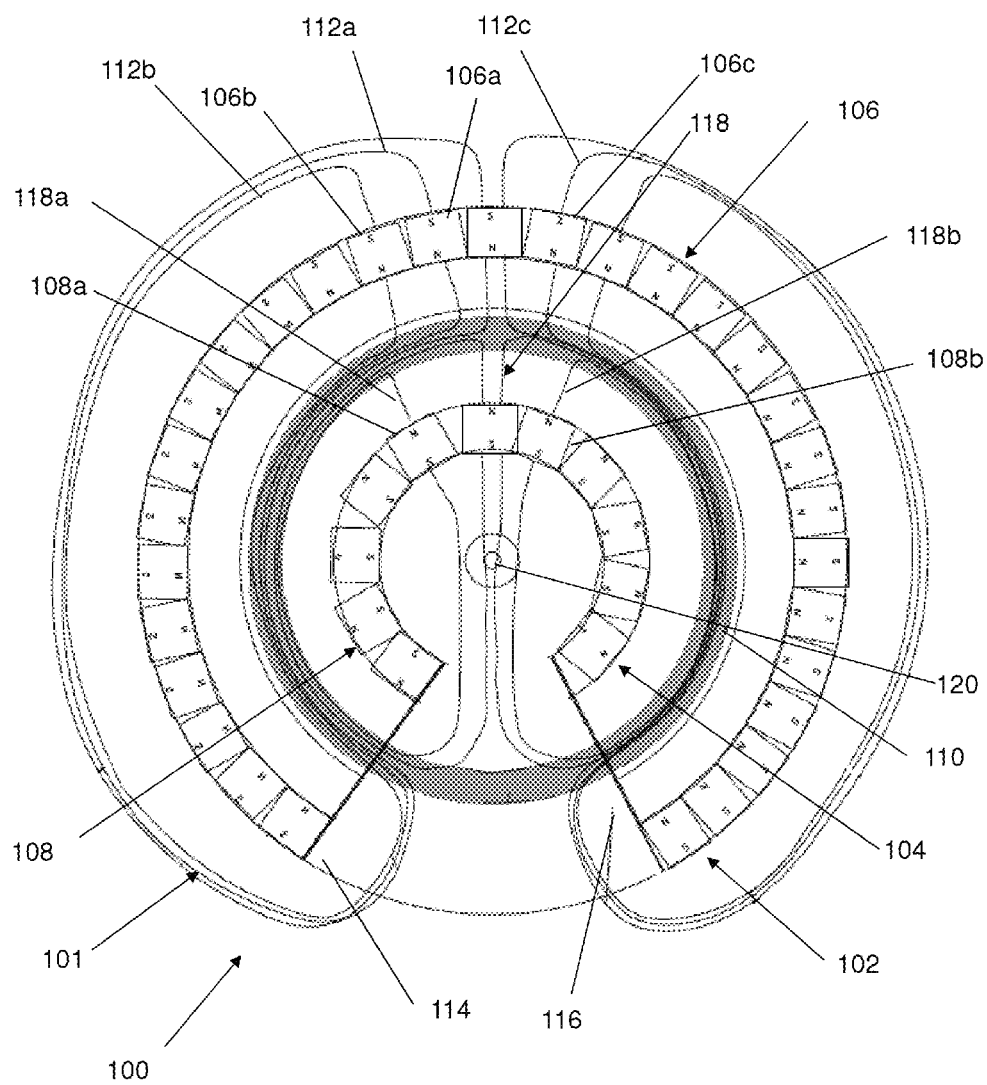


Fig. 1

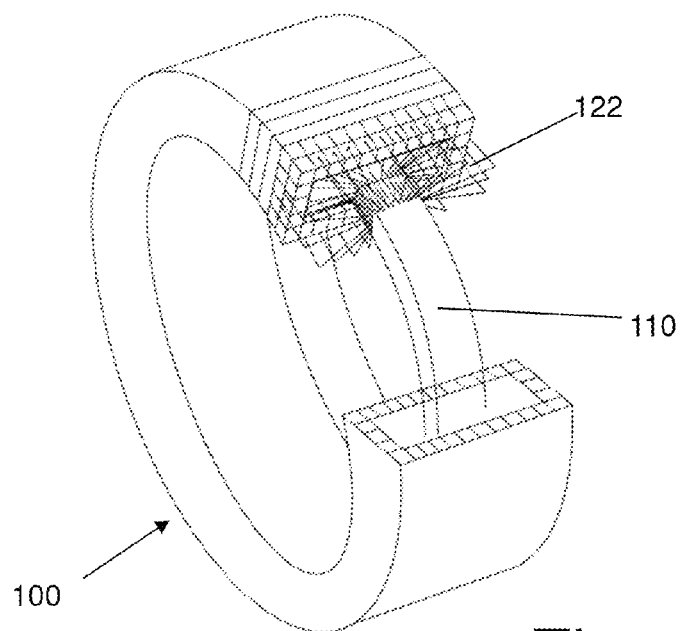


Fig. 2a

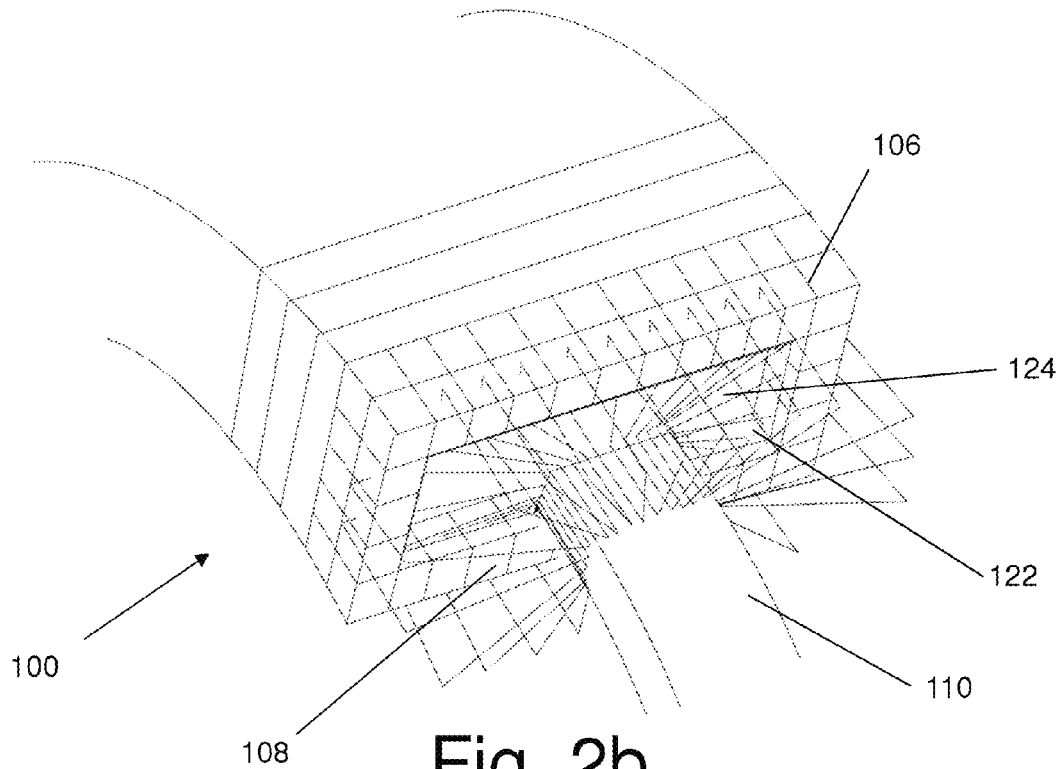


Fig. 2b

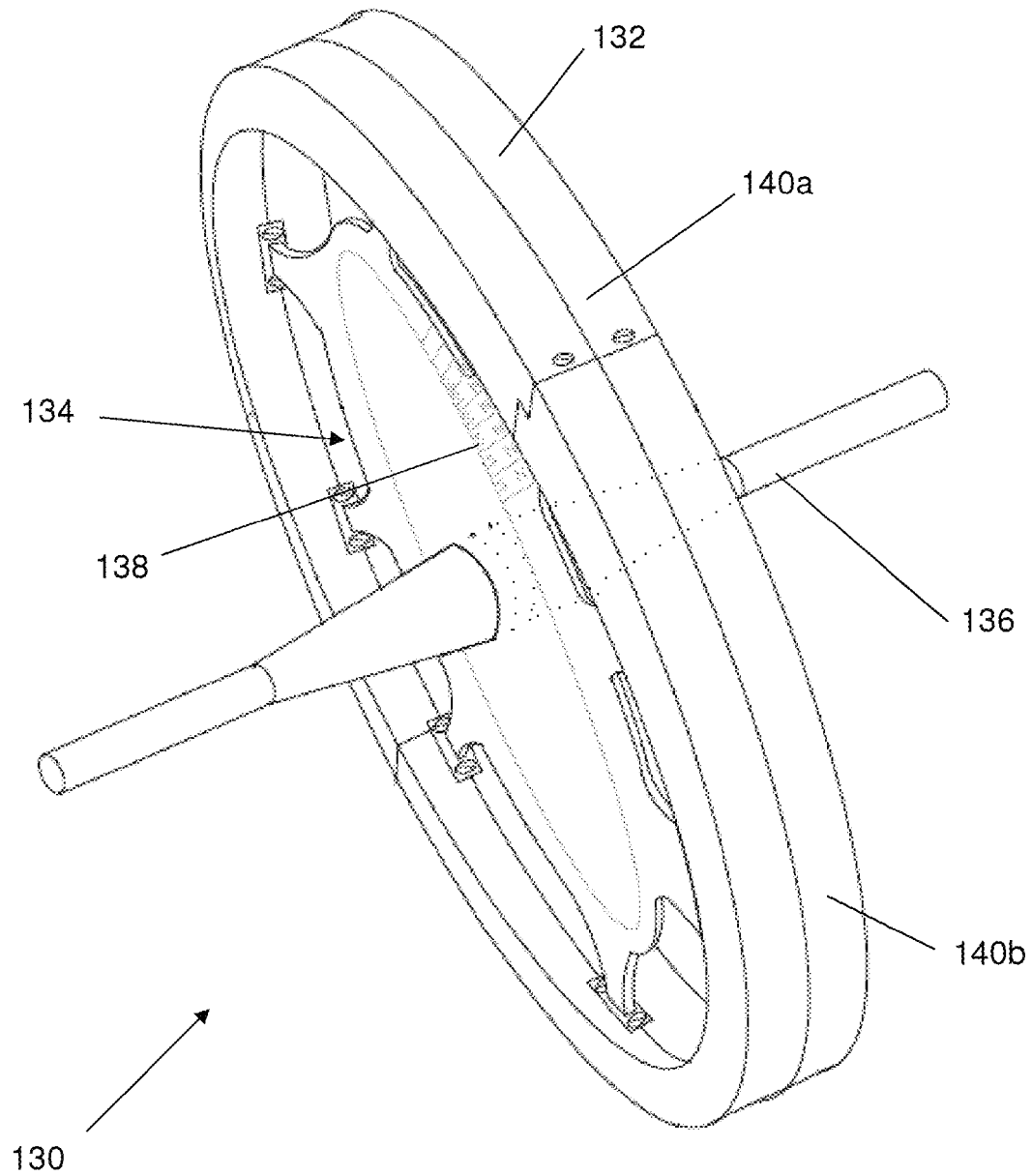


Fig. 3

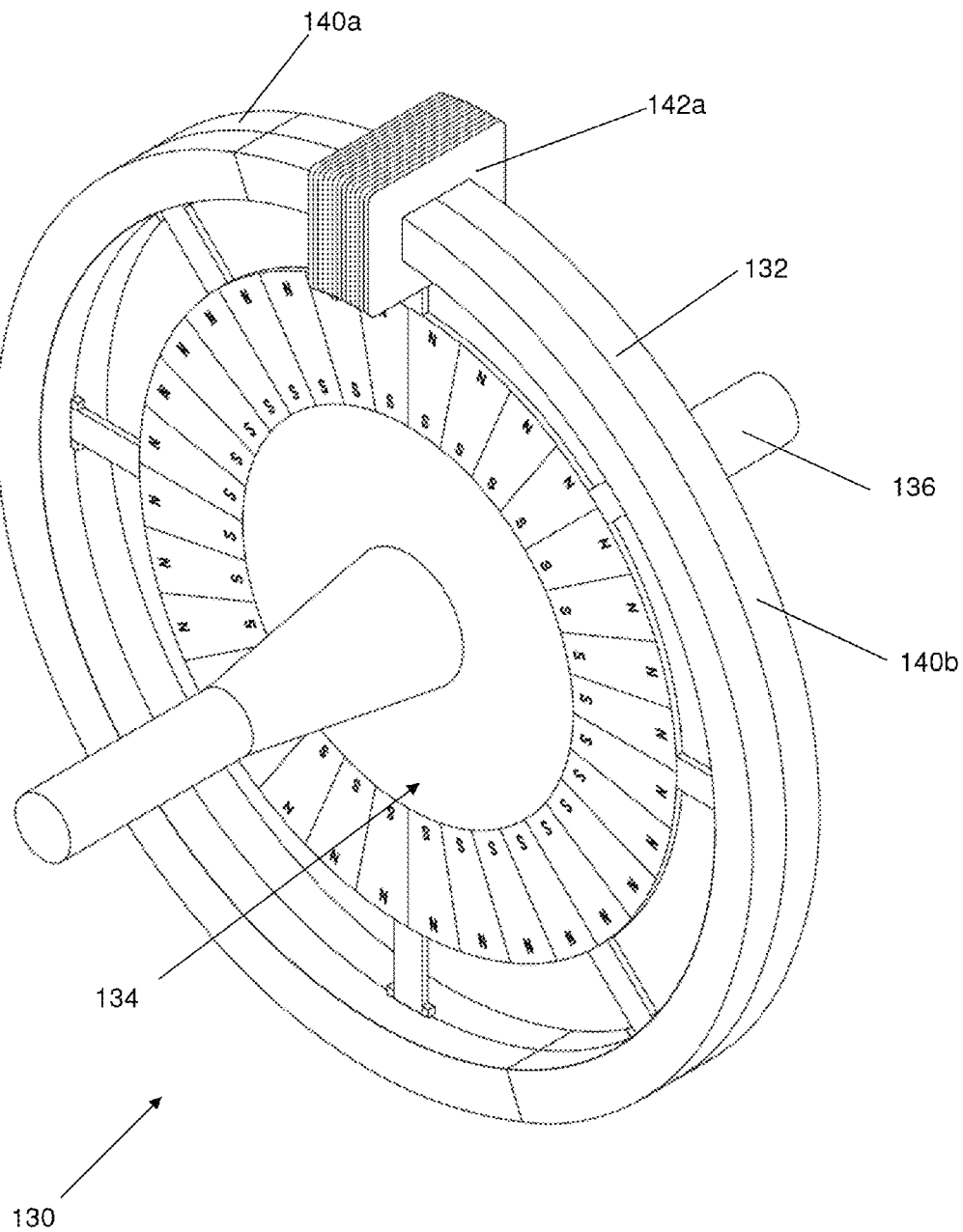


Fig. 4

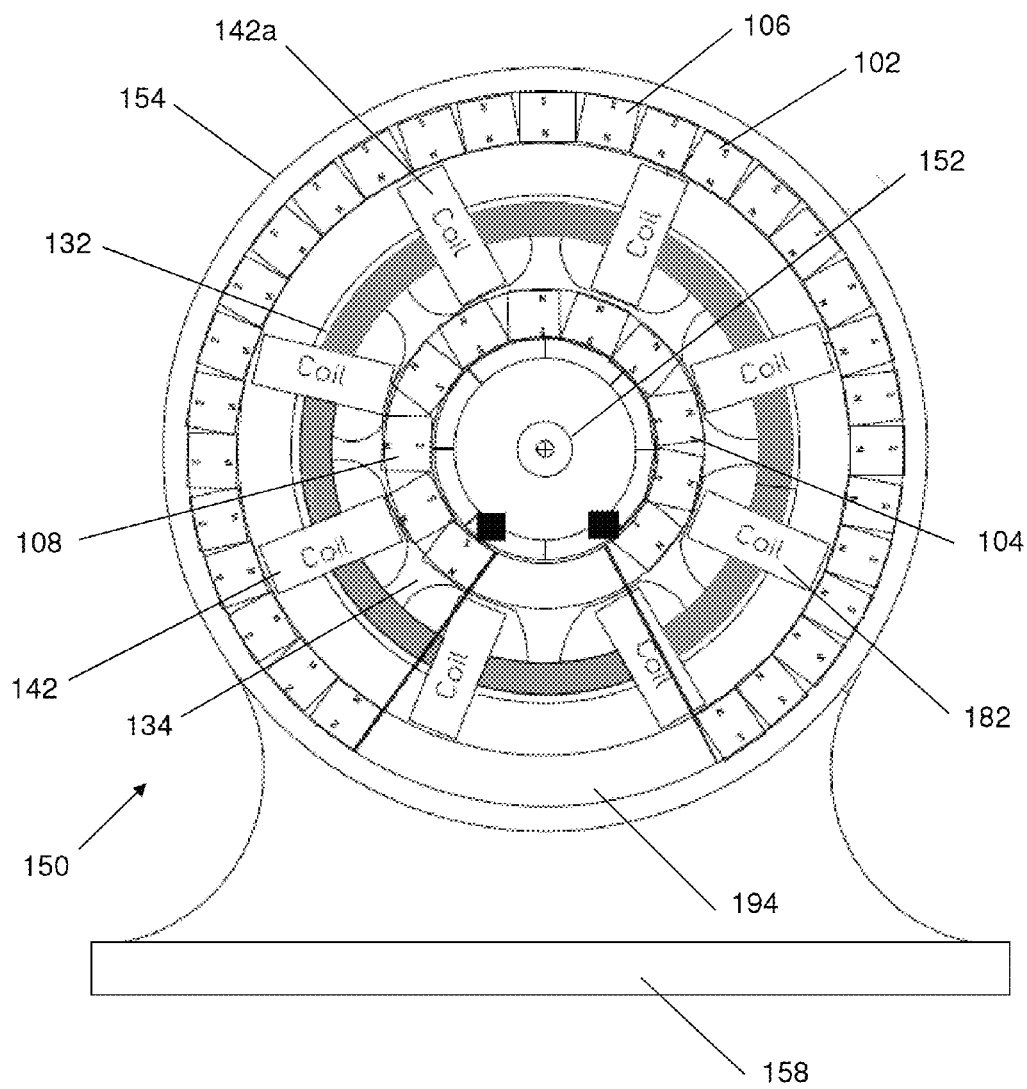


Fig. 5

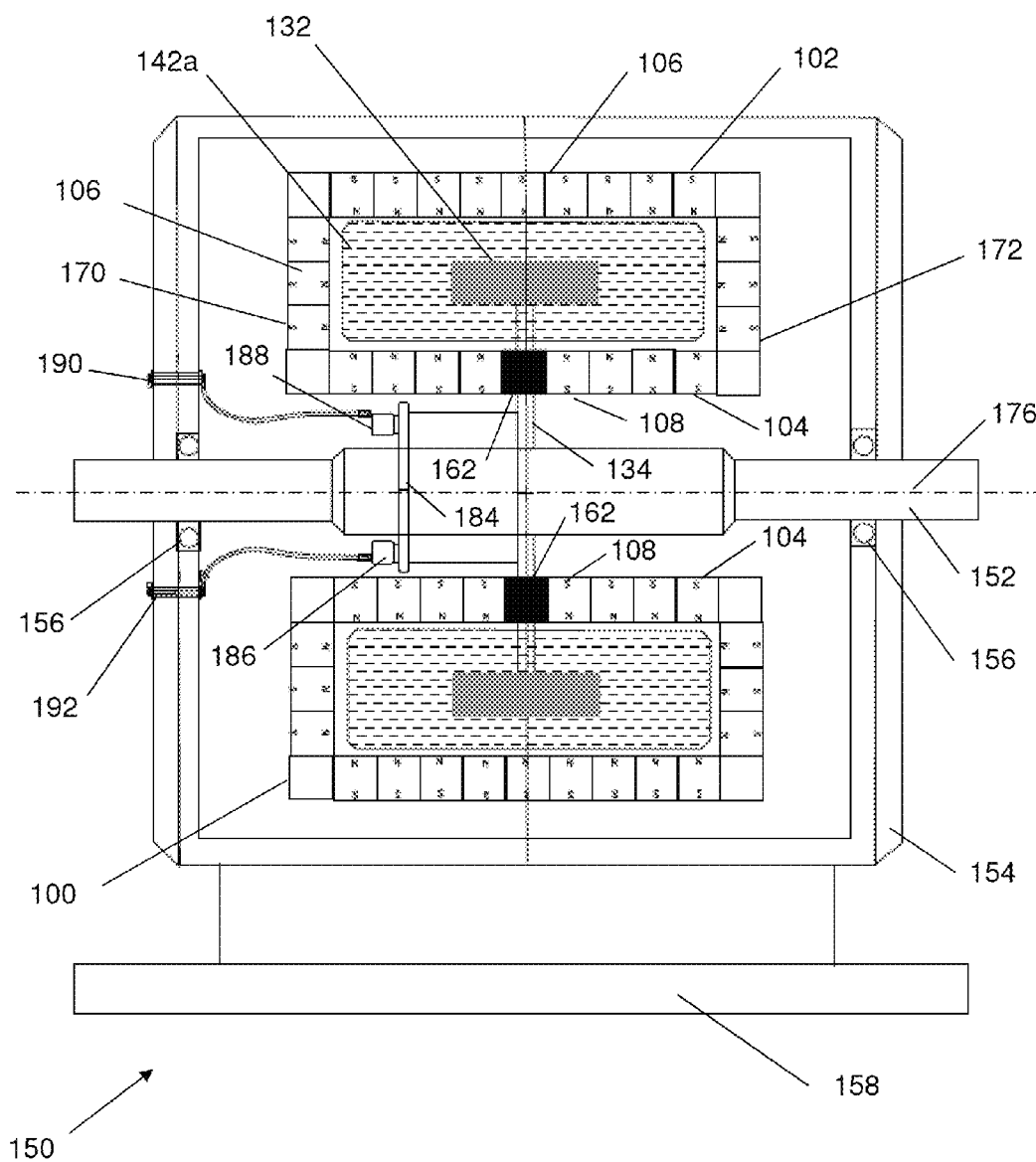


Fig. 6

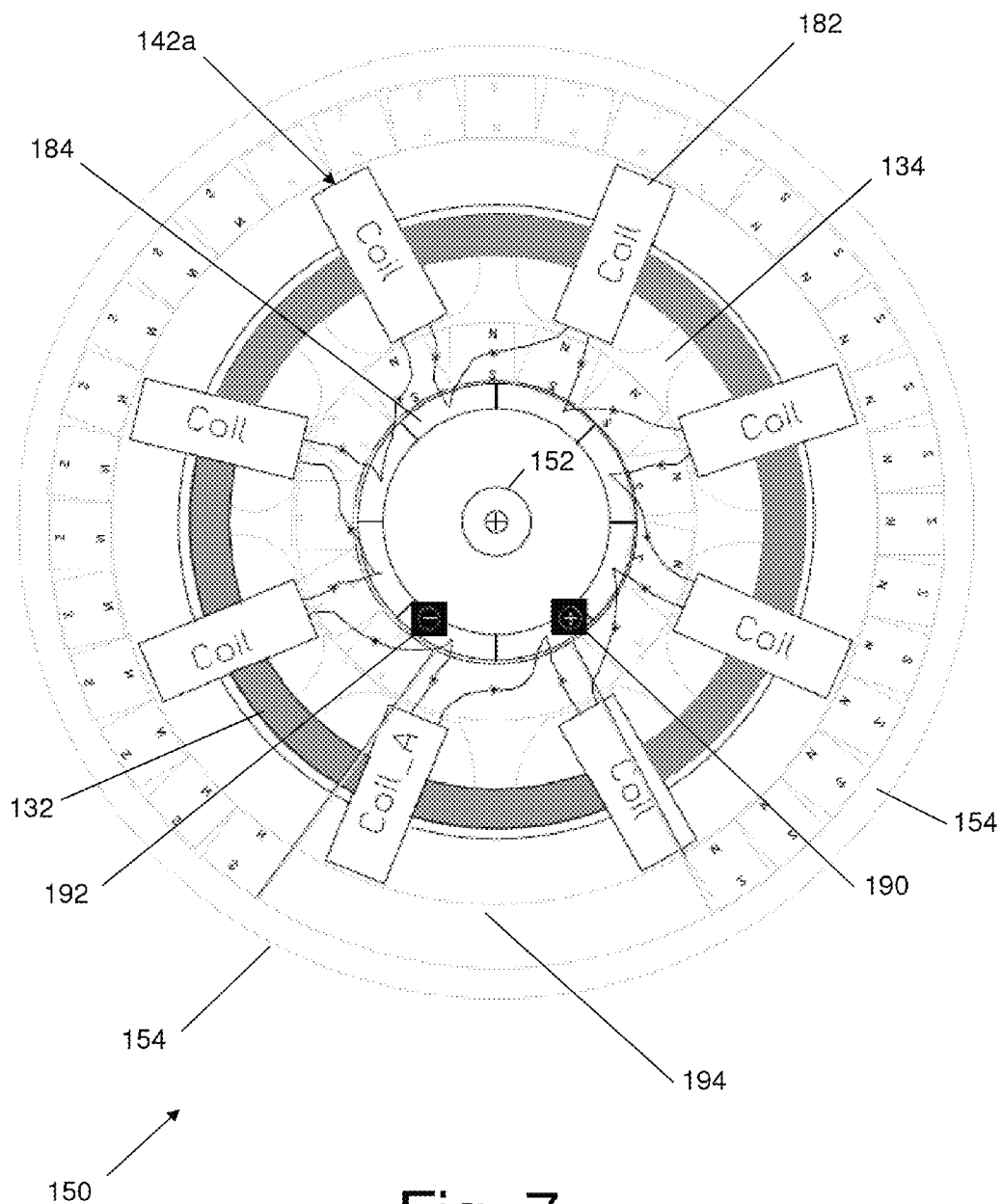
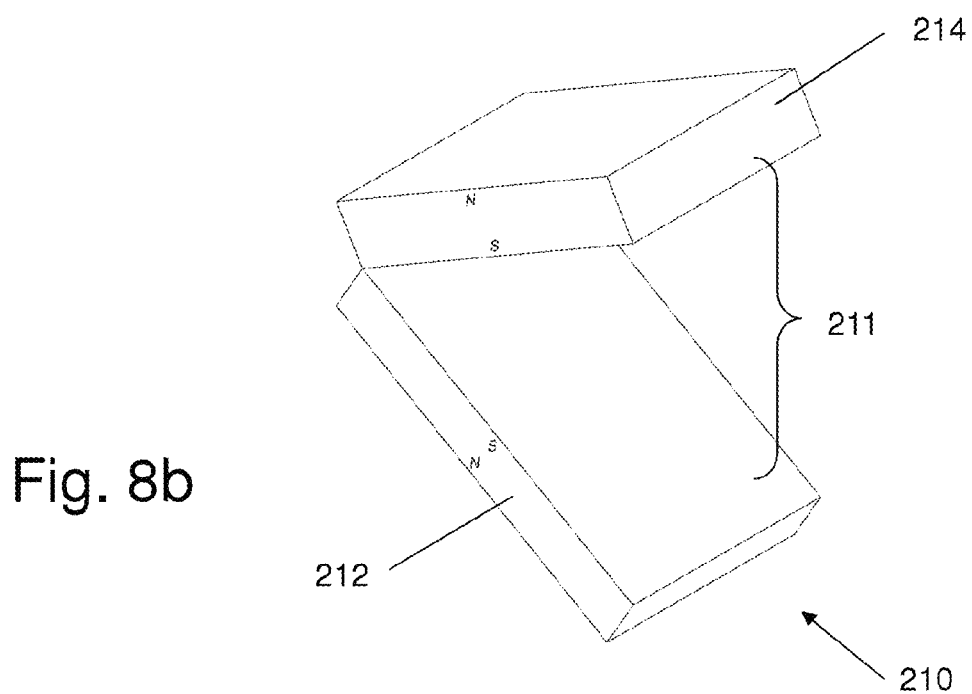
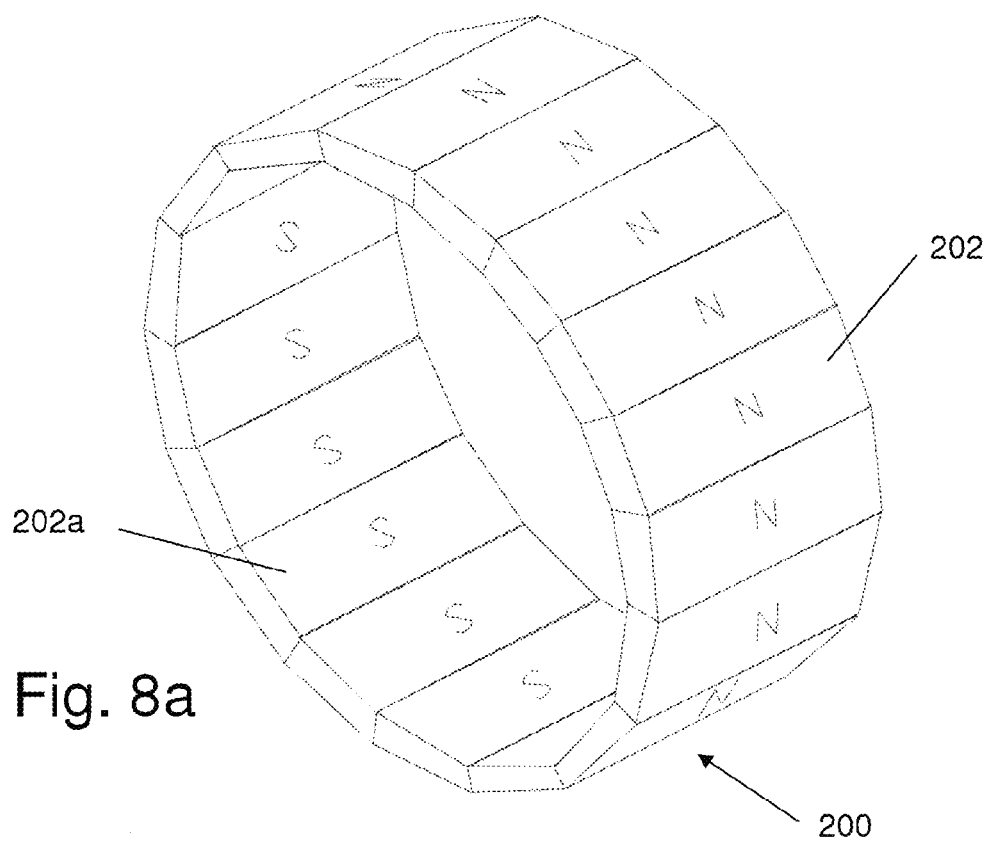
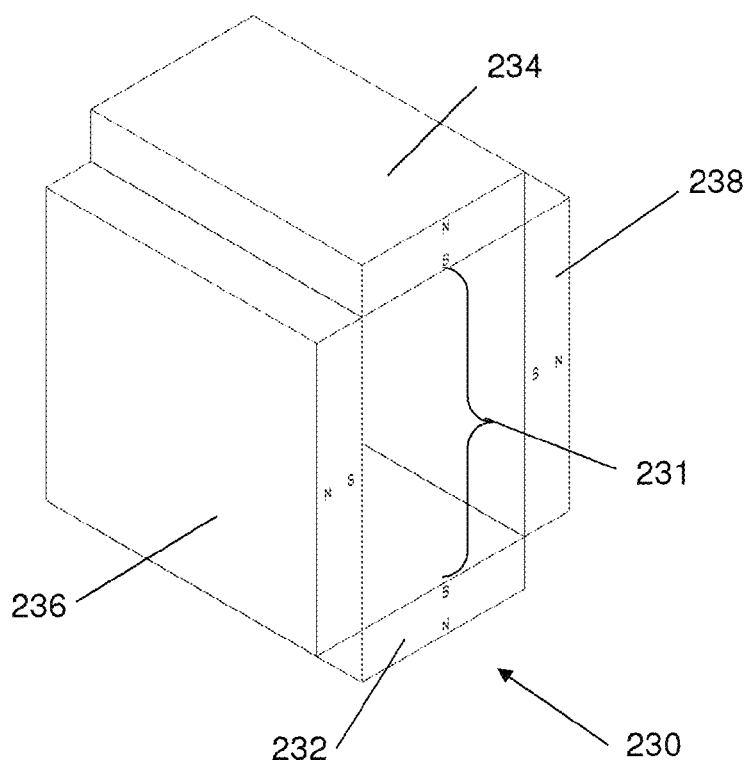
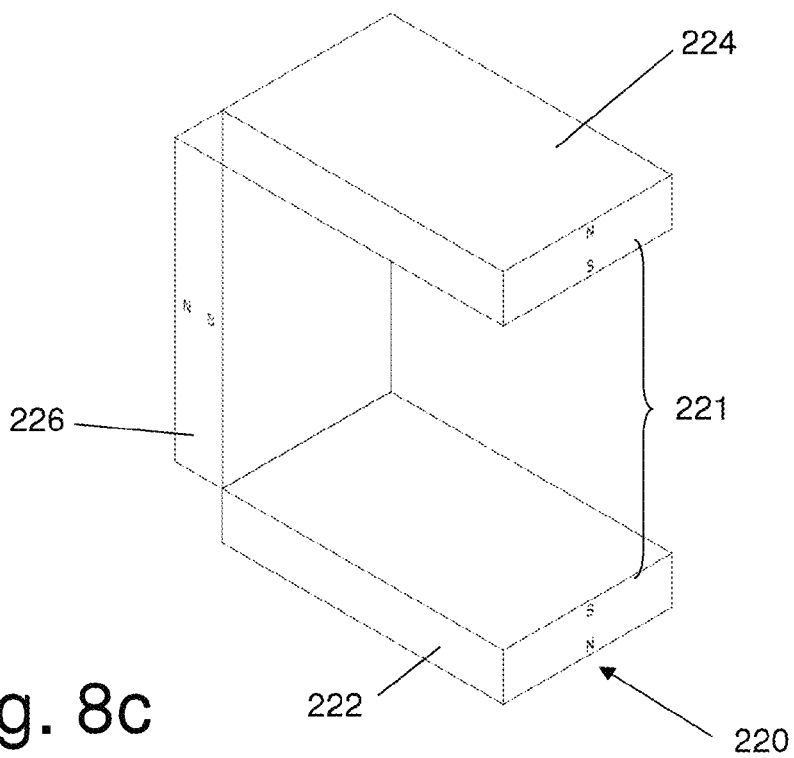


Fig. 7





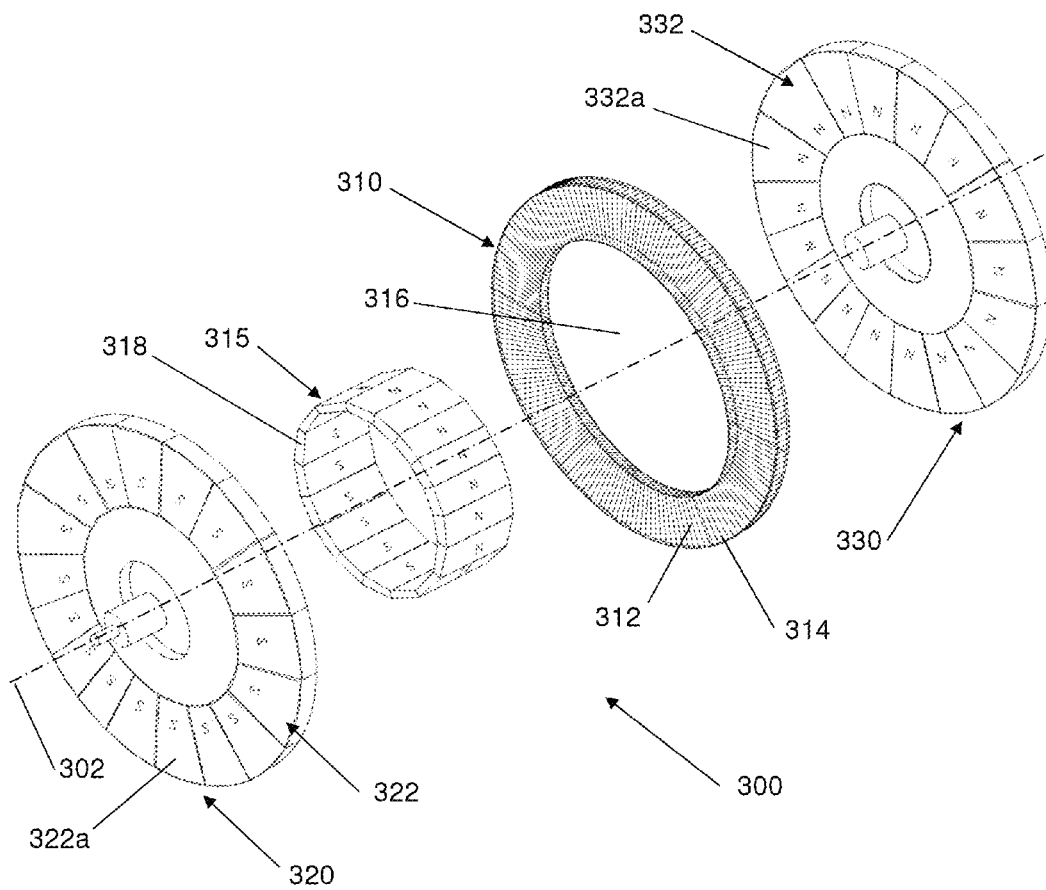


Fig. 9a

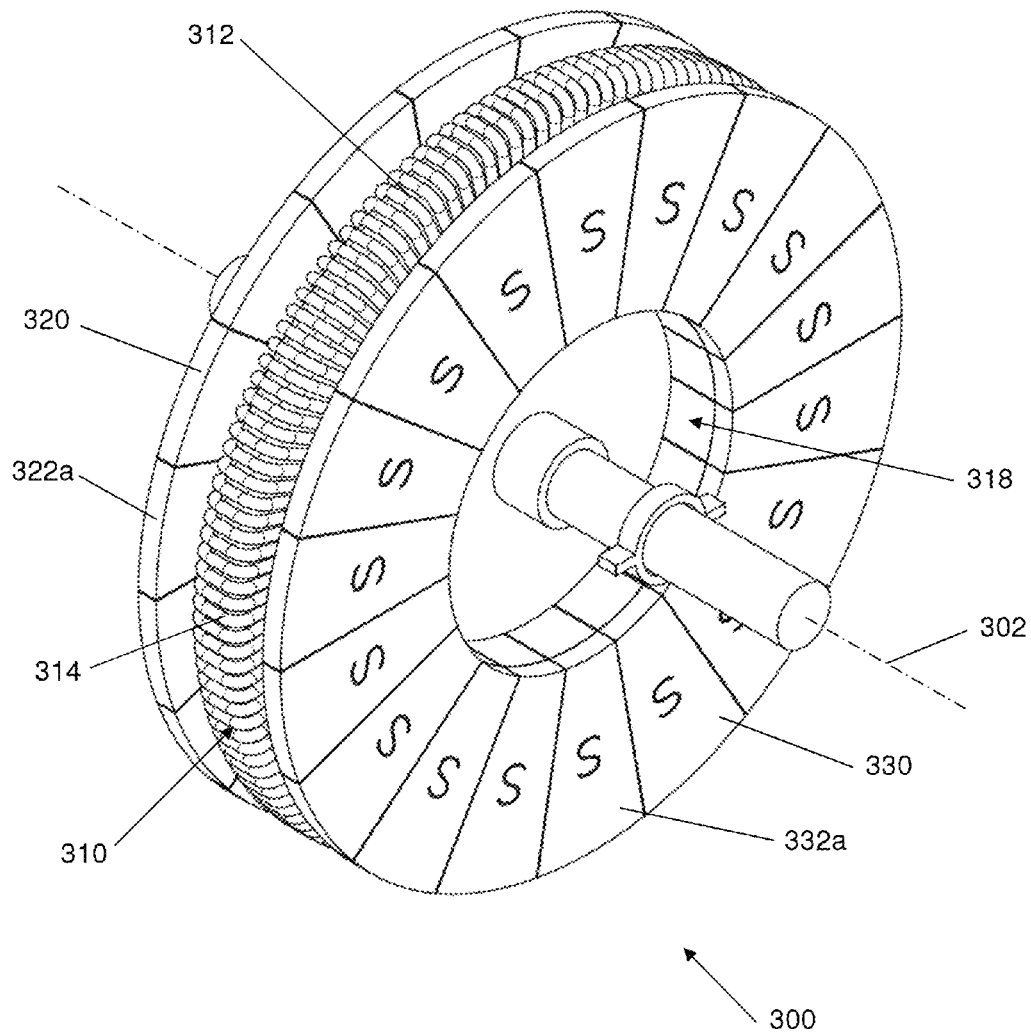


Fig. 9b

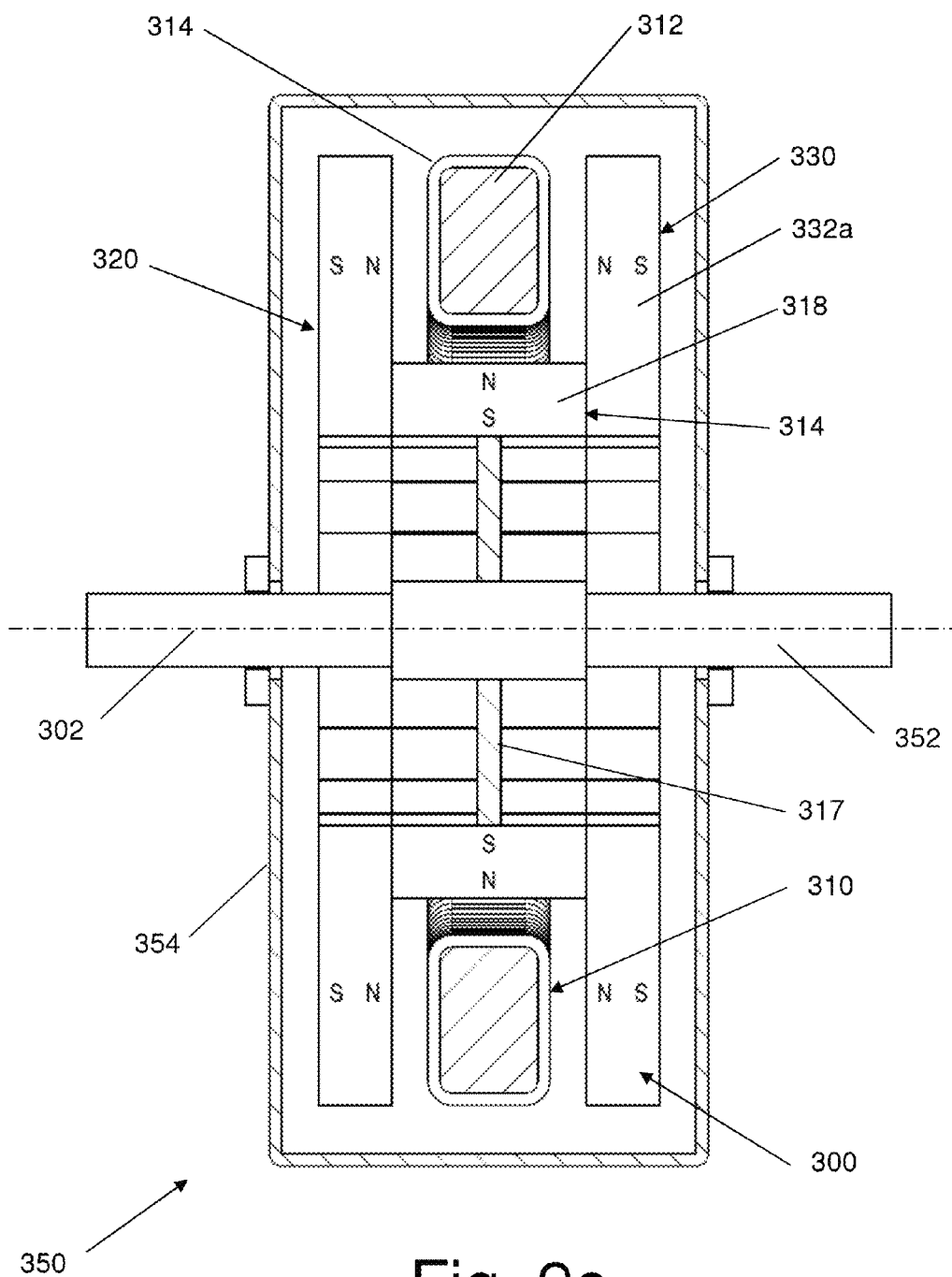


Fig. 9c

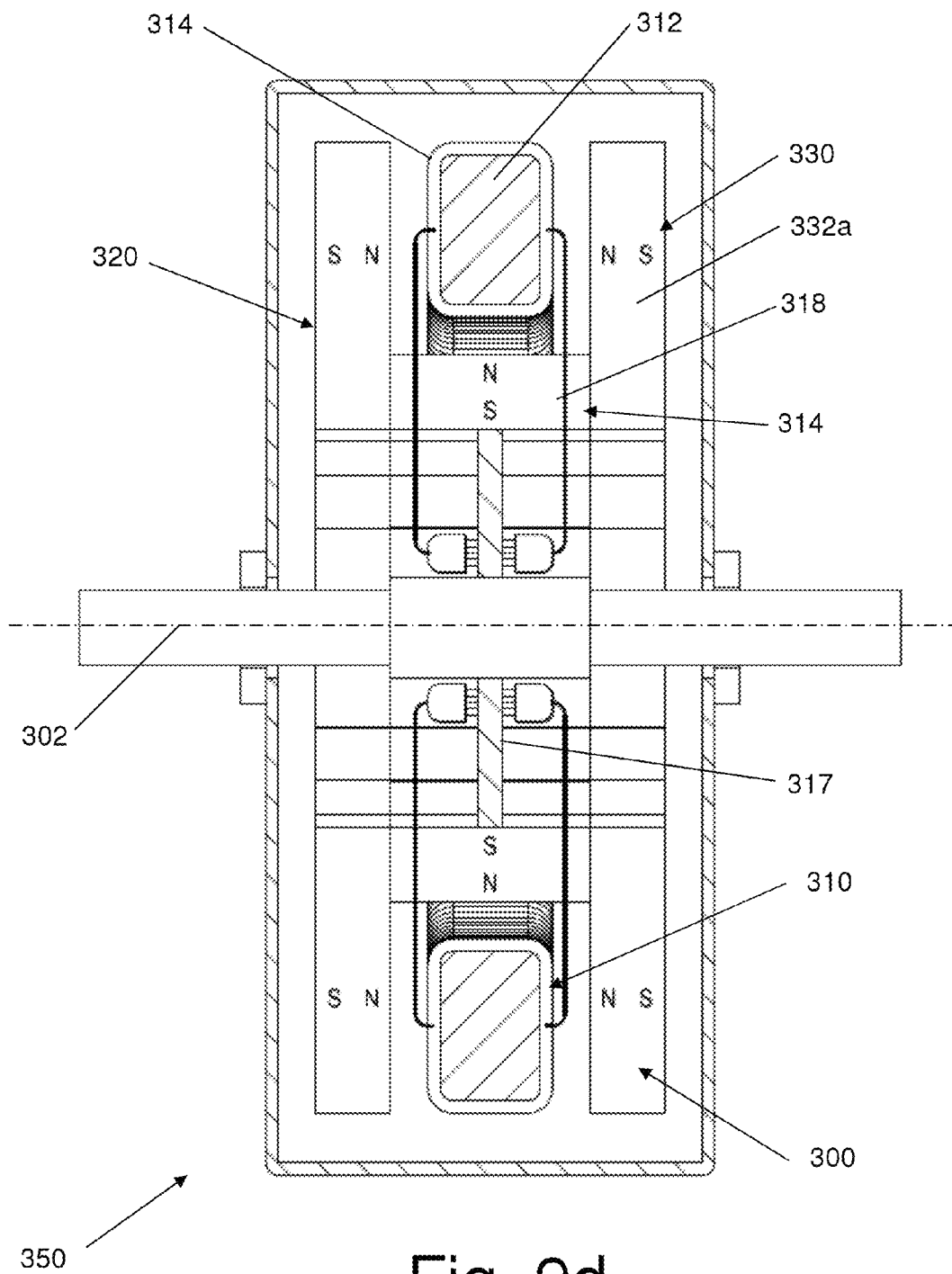


Fig. 9d

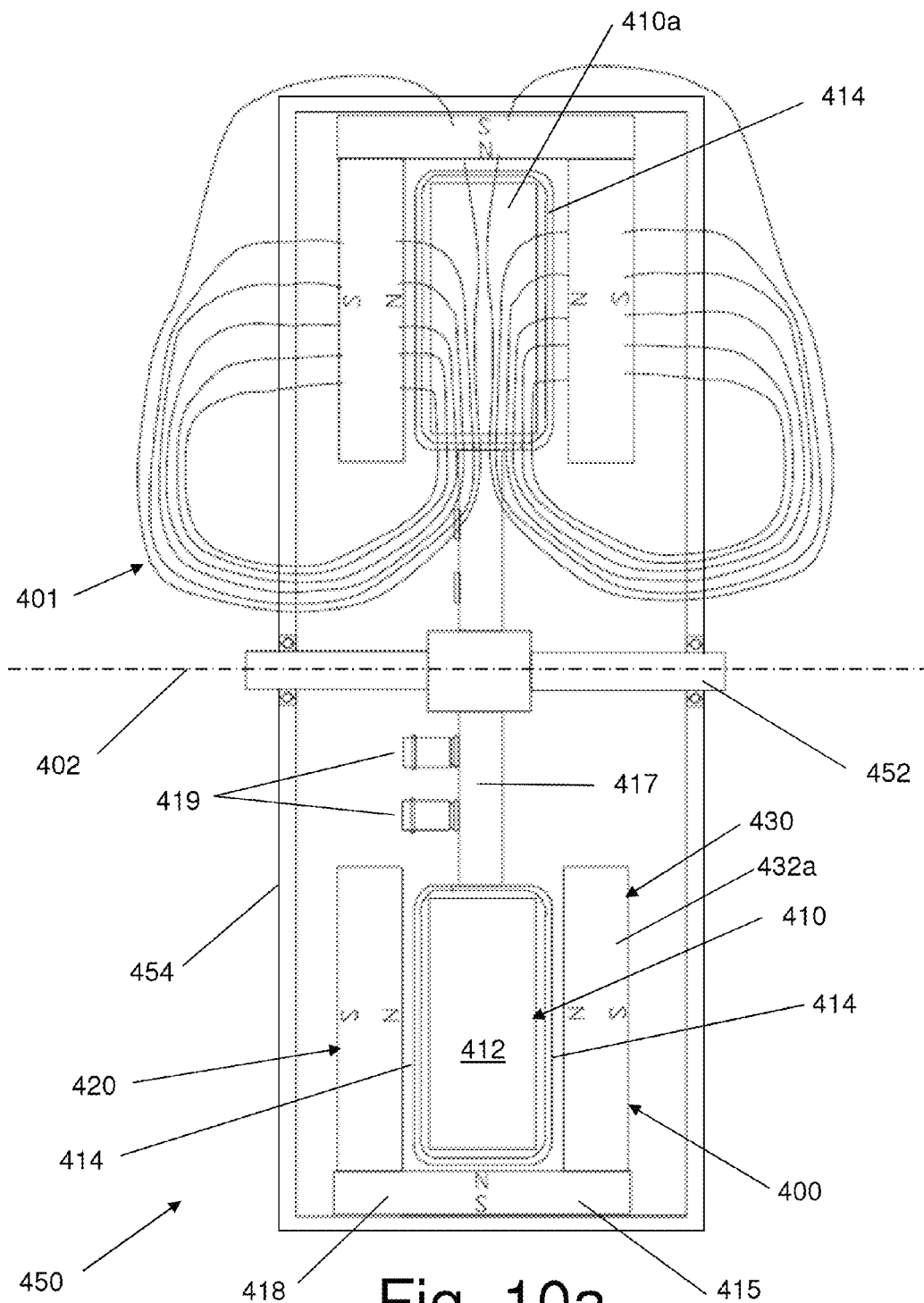
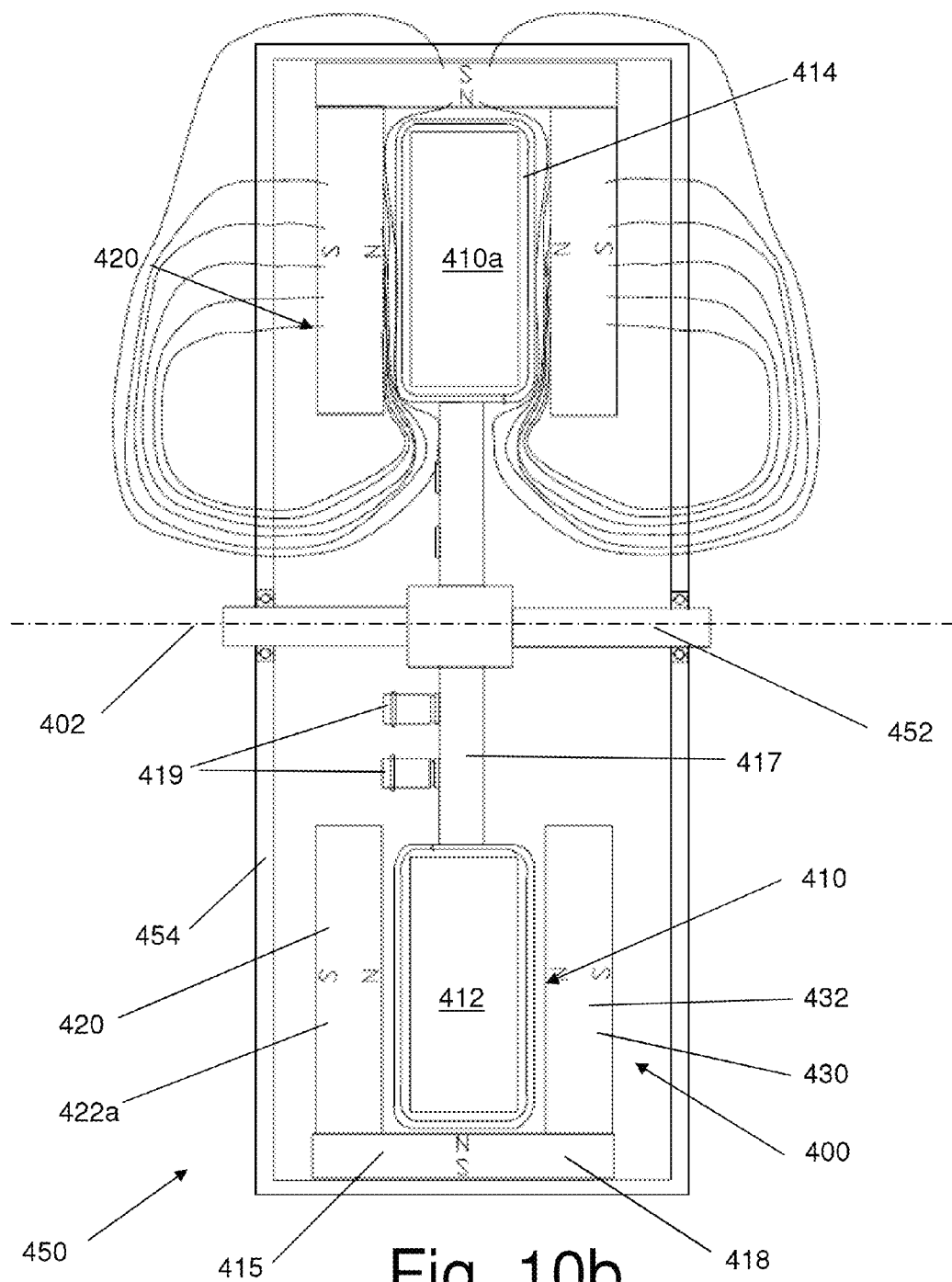


Fig. 10a



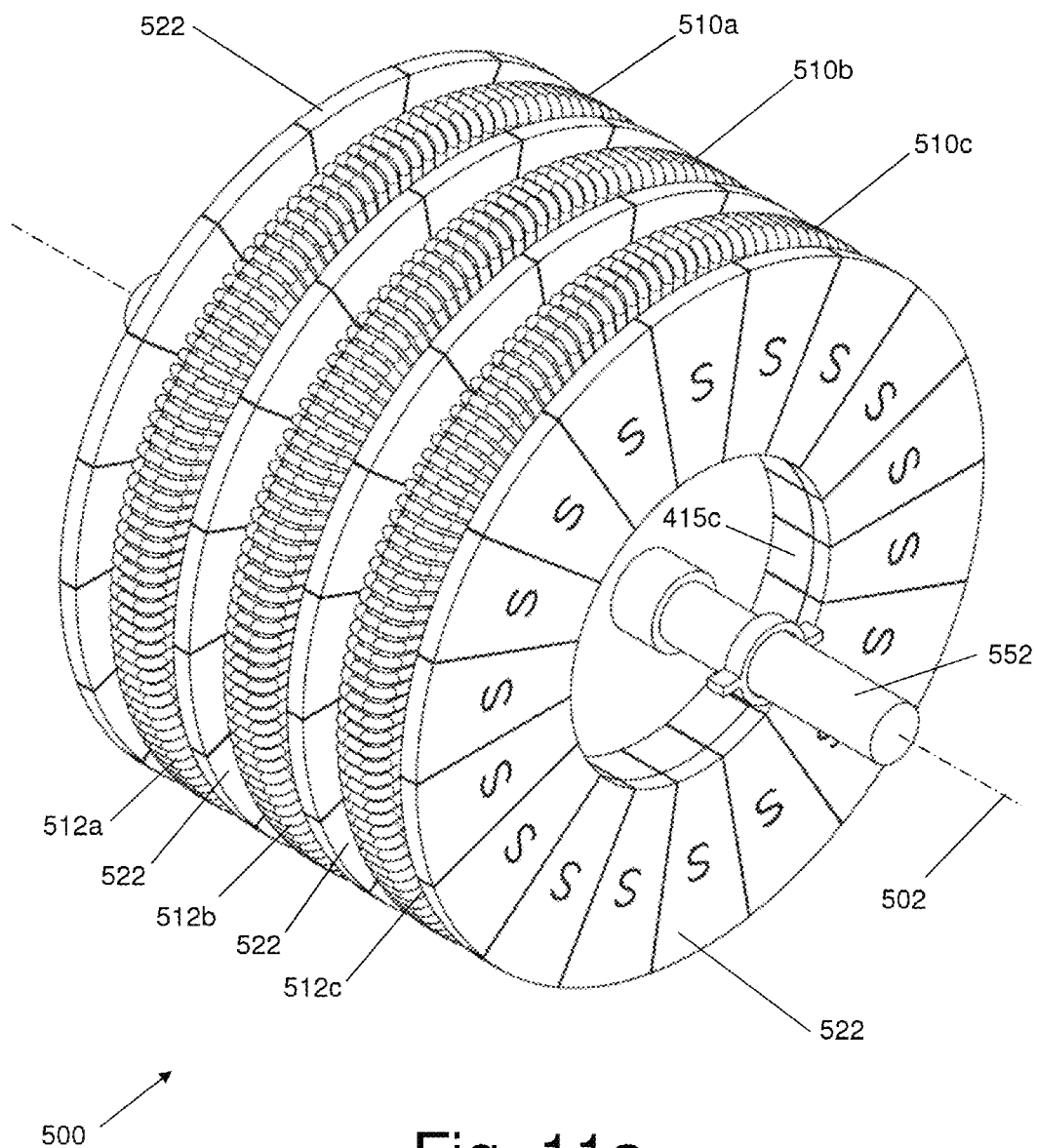


Fig. 11a

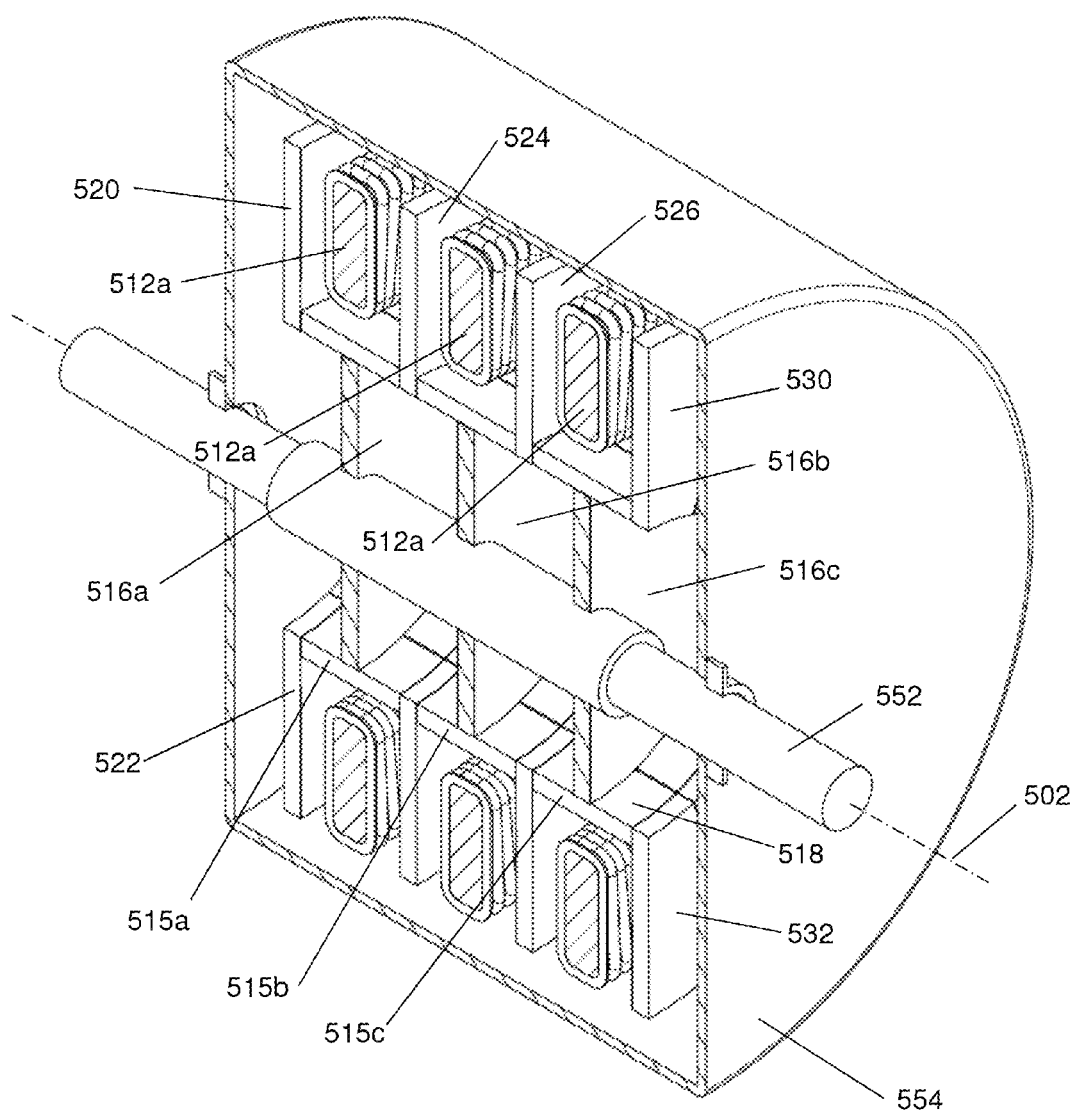
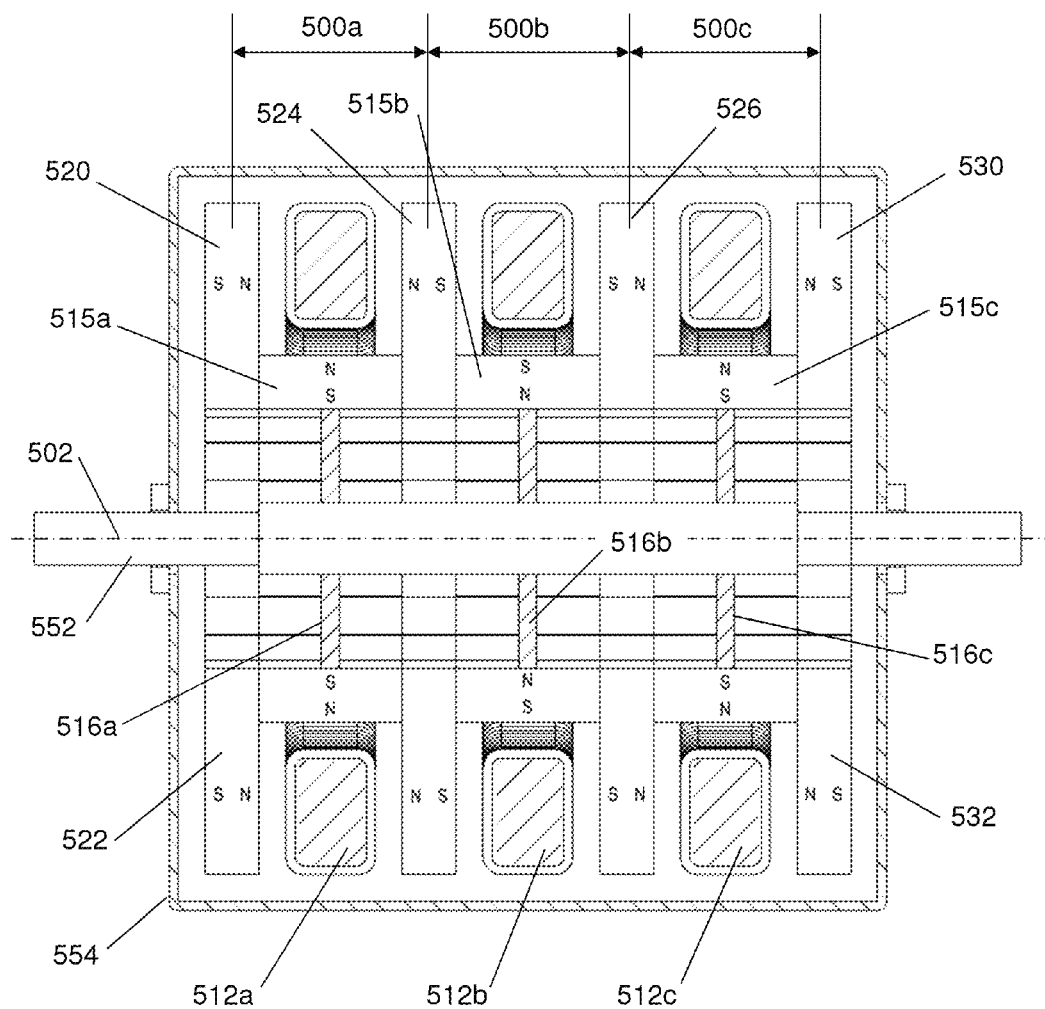
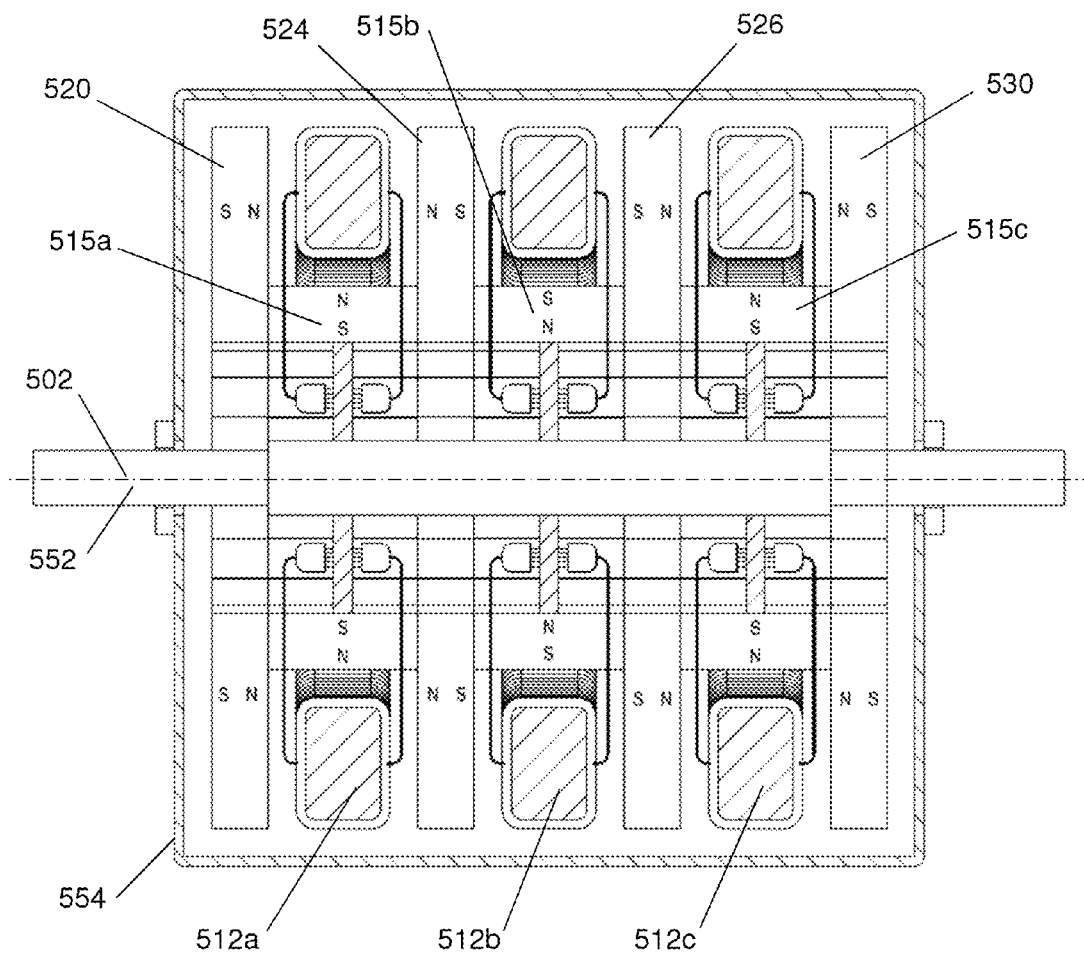


Fig. 11b



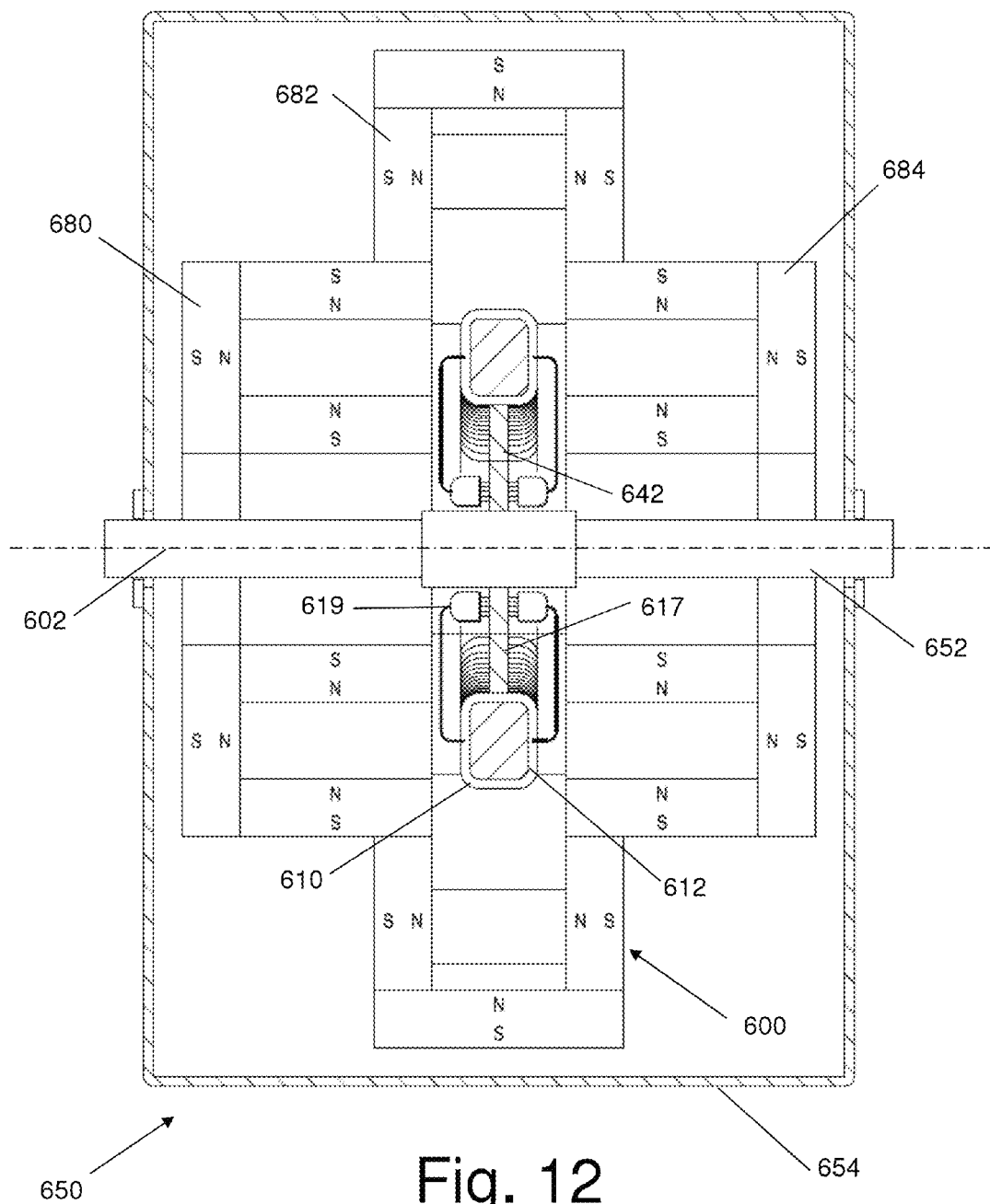
550

Fig. 11c



550

Fig. 11d



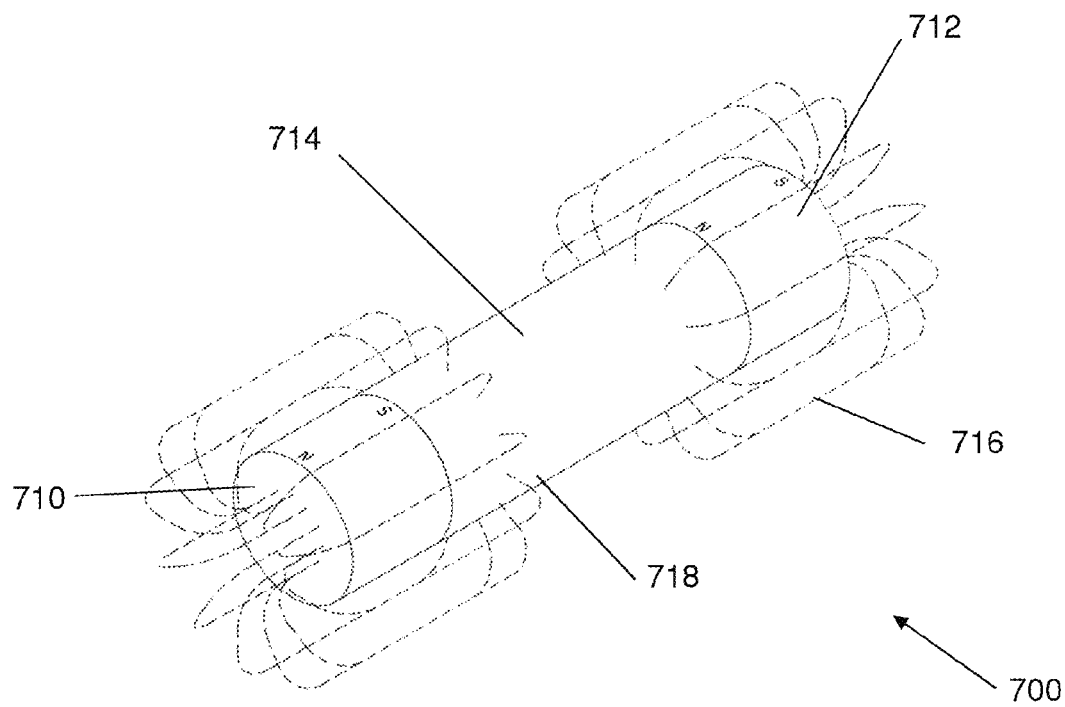


Fig. 13a

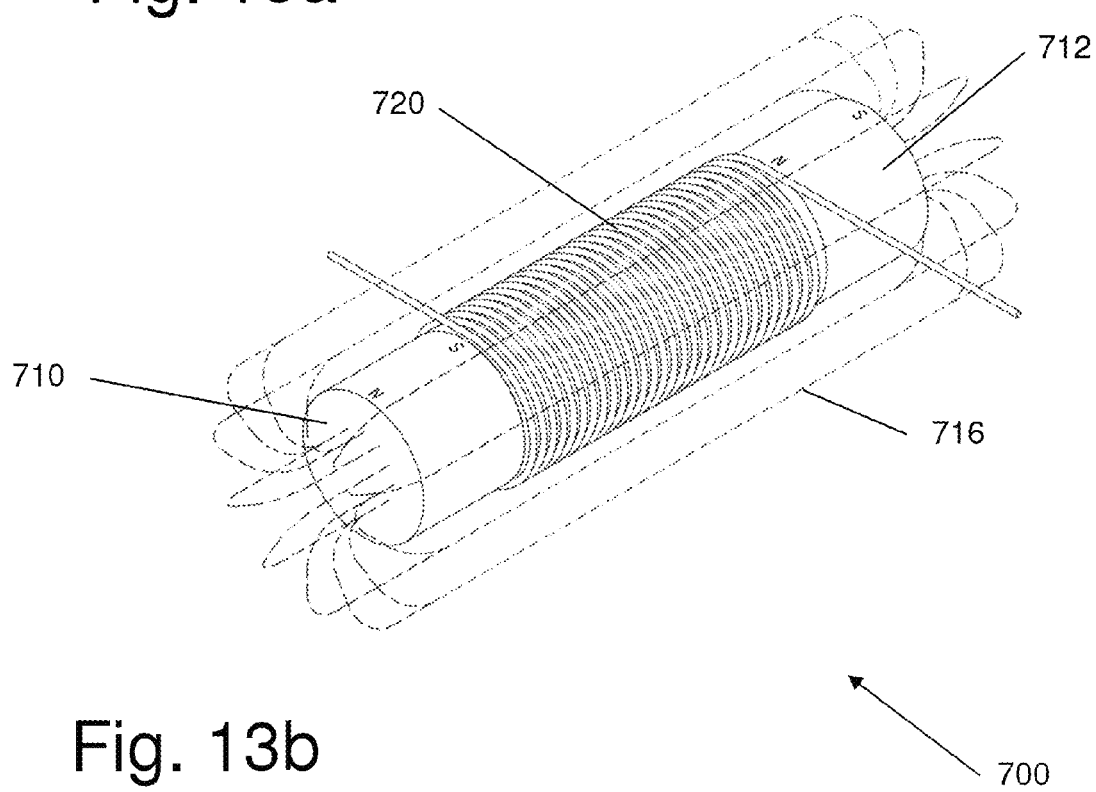


Fig. 13b

1

DC ELECTRIC MOTOR/GENERATOR WITH ENHANCED PERMANENT MAGNET FLUX DENSITIES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing date of U.S. provisional patent application Ser. No. 61/613,022, filed on Mar. 20, 2012, entitled "An Improved Electric Motor Generator," the disclosure of which is incorporated herein by reference for all purposes. This application is also related to a PCT application entitled "AN IMPROVED DC ELECTRIC MOTOR/GENERATOR WITH ENHANCED PERMANENT MAGNET FLUX DENSITIES" filed on Mar. 20, 2013, the disclosure of this application is also incorporated by reference for all purposes.

TECHNICAL FIELD

The invention relates in general to a new and improved electric motor/generator, and in particular to an improved system and method for producing rotary motion from an electro-magnetic motor or generating electrical power from a rotary motion input.

BACKGROUND INFORMATION

Electric motors use electrical energy to produce mechanical energy, very typically through the interaction of magnetic fields and current-carrying conductors. The conversion of electrical energy into mechanical energy by electromagnetic means was first demonstrated by the British scientist Michael Faraday in 1821 and later quantified by the work of Hendrik Lorentz.

A magnetic field is generated when electric charge carriers such as electrons move through space or within an electrical conductor. The geometric shapes of the magnetic flux lines produced by moving charge carriers (electric current) are similar to the shapes of the flux lines in an electrostatic field. Magnetic flux passes through most metals with little or no effect, with certain exceptions, notably iron and nickel. These two metals, and alloys and mixtures containing them, are known as ferromagnetic materials because they concentrate magnetic lines of flux. Areas of greatest field strength or flux concentration are known as magnetic poles.

In a traditional electric motor, a central core of tightly wrapped current carrying material creates magnetic poles (known as the rotor) which spins or rotates at high speed between the fixed poles of a magnet (known as the stator) when an electric current is applied. The central core is typically coupled to a shaft which will also rotate with the rotor. The shaft may be used to drive gears and wheels in a rotary machine and/or convert rotational motion into motion in a straight line.

Generators are usually based on the principle of electromagnetic induction, which was discovered by Michael Faraday in 1831. Faraday discovered that when an electrical conducting material (such as copper) is moved through a magnetic field (or vice versa), an electric current will begin to flow through that material. This electromagnetic effect induces voltage or electric current into the moving conductors.

Current power generation devices such as rotary alternator/generators and linear alternators rely on Faraday's discovery to produce power. In fact, rotary generators are essentially very large quantities of wire spinning around the inside of

2

very large magnets. In this situation, the coils of wire are called the armature because they are moving with respect to the stationary magnets (which are called the stators). Typically, the moving component is called the armature and the stationary components are called the stator or stators.

Motors and generators used today produce or utilize a sinusoidal time varying voltage. This waveform is inherent to the operation of these devices.

In most conventional motors, both linear and rotating, enough power of the proper polarity must be pulsed at the right time to supply an opposing (or attracting) force at each pole segment to produce a particular torque. In conventional motors at any given instant only a portion of the coil pole pieces is actively supplying torque.

With conventional motors a pulsed electrical current of sufficient magnitude must be applied to produce a given torque/horsepower. Horsepower output and efficiency then is a function of design, electrical input power plus losses.

With conventional generators, an electrical current is produced when the rotor is rotated. The power generated is a function of flux strength, conductor size, number of pole pieces and speed in RPM. However output is a sinusoidal output with the same losses as shown in conventional electric motors.

A conventional linear motor/generator, on the other hand, may be visualized as a typical electric motor/generator that has been cut open and unwrapped. The "stator" is laid out in the form of a track of flat coils made from aluminum or copper and is known as the "primary" of a linear motor. The "rotor" takes the form of a moving platform known as the "secondary." When the current is switched on, the secondary glides past the primary supported and propelled by a magnetic field. A Linear generator works in the same manner but mechanical power provides the force to move the rotor or secondary past magnetic fields.

In traditional generators and motors, the pulsed time varying magnetic fields produces undesired effects and losses, i.e. Iron Hysteresis losses, Counter-EMF, inductive kickback, eddy currents, inrush currents, torque ripple, heat losses, cogging, brush losses, high wear in brushed designs, commutation losses and magnetic buffeting of permanent magnets. In many instances, complex controllers are used in place of mechanical commutation to address some of these effects.

In motors and generators that utilize permanent magnets it is desirable to increase magnetic flux densities to achieve more efficient operation. Most permanent magnet motor/generators used today rely on permanent magnets such as Neodymium magnets. These magnets are the strongest of the man made magnetic materials. Due to their strategic value to industry and high costs it is desirable to increase flux densities without relying on a breakthrough in material composition of these magnets or manufacturing high density special purpose magnet shapes and sizes.

In motors or generators, some form of energy drives the rotation and/or movement of the rotor. As energy becomes more scarce and expensive, what is needed are more efficient motors and generators to reduce energy costs.

SUMMARY

In response to these and other problems, there is presented various embodiments disclosed in this application, including methods and systems of increasing flux density by permanent magnet manipulation. Specifically, methods and systems of increasing flux density utilizing commercially available shapes or sizes that can be chosen based on lower cost rather than flux density. Also described are methods of producing

3

mechanical power by moving a coil/s coupled to a core into a magnet assembly with an increased flux density or producing an electrical output power when the coils are mechanically forced through the magnetic assembly with an increased flux density. In certain aspects, within the magnetic cylinder or magnet assembly magnetic flux lines are created and increased by the configuration of permanent magnets or electromagnets and are restrained within the magnetic cylinder or magnet assembly until exiting at predetermined locations.

In certain aspects presented herein, non-pulsating or non-sinusoidal DC current is applied to the power terminals which produces a Lorentz force at each length of coil conductor. This force is applied continuously throughout the entire rotation of the rotor hub without variations in amplitude or interruptions in output power. There are no pole pieces to provide magnetic attraction or repulsion thus there is no torque ripple, polarity reversals or interruptions in power output while the poles are in the process of reversing, producing more efficient output than traditional motors

When certain aspects of the disclosed embodiments are used as a generator non pulsating or non-sinusoidal DC current is produced at the power terminals. A Lorentz force at each length of coil conductor and across all coils induces an output current flow. This output is supplied continuously throughout the entire rotation of the rotor hub without variations in amplitude, polarity reversals, or interruptions in output power. There are no pole pieces to provide magnetic attraction or repulsion which produces a current output more efficiently than traditional generators.

Certain aspects of the disclosure reduces or eliminates the undesired effects and losses of traditional generators and motors discussed above, including Iron Hysteresis losses, Counter-EMF, inductive kickback, eddy currents, inrush currents, torque ripple, heat losses, cogging, brush losses, sparking and high wear in brushed designs, commutation losses and magnetic buffeting of permanent magnets.

In summary, certain aspects of the various disclosed embodiments may provide the following benefits:

Unlike conventional brush rectified or PWM controller motor/generators, the coils in aspects of this invention are in continuous contact with the Permanent Magnet field and thus produce a non-varying continuous torque or output.

Complex PWM drives and controllers, commutators, etc (and the associated losses) may not be not required since certain aspects of the invention produce and utilize DC current directly.

If automatic speed control for a given load is required, complex position indication is not required. A much simpler RPM indication and a varying voltage/current relationship is all that is required.

Using the magnetic cylinder/single pole magnet assembly concept utilizing permanent magnets an otherwise unachievable, extremely strong magnetic field is generated without consuming any electrical power.

Though a Counter EMF field is produced by any induced current flow, due to the magnet cylinder and core design there is no direct impact on coil movement that hinders such movement.

Iron Hysteresis losses are essentially eliminated as only two points on the core experience any hysteresis loss at all and then only twice per revolution.

Eddy current losses are essentially eliminated as the core does not move perpendicular to the flux lines

Cogging is also essentially eliminated as the core forces are balanced and equal in all directions

There is little inrush current as there is no need to saturate large masses of iron

4

100% of the copper windings in the coil is utilized to take advantage of Lorentz forces thus there is no wasted copper winding as in conventional motor/generators.

Inductive kickback from the rising and collapsing sinusoidal waveform is eliminated

Like other DC motors reversal of torque is simply a reversal of input polarities.

These and other features, and advantages, will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings.

It is important to note the drawings are not intended to represent the only aspect of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a toroidal magnetic cylinder illustrating representative "planar" portions of magnetic flux paths within and around the cylinder with an iron core.

FIG. 2a is an isometric and partial section view of a toroidal magnetic cylinder of FIG. 1.

FIG. 2b is a detailed partial section view of the toroidal magnetic cylinder of FIG. 1a illustrating the planar magnetic fields or flux walls generated within the cylinder interior.

FIG. 3 is a conceptualized isometric view of a rotor hub assembly.

FIG. 4 is a conceptualized isometric view of a rotor hub assembly with a coil positioned on the rotor assembly.

FIG. 5 is a conceptualized lateral section view of an electric motor/generator assembly using the rotor hub assembly illustrating the power terminals and segmented single slip ring brush assembly configuration.

FIG. 6 is a conceptualized longitudinal section view of the electric motor/generator assembly of FIG. 5.

FIG. 7 is a lateral section view illustrating one embodiment of a coupling system between a portion of the coils and the slip ring segments which may be used with the electric motor/generator of FIG. 5.

FIG. 8a is an isometric view of a magnetic ring.

FIG. 8b is a detailed isometric view of a portion of an alternative embodiment of a magnetic ring.

FIG. 8c is a detailed isometric view of a portion of an alternative embodiment of a magnetic ring.

FIG. 8d is a detailed isometric view of a portion of an alternative embodiment of a magnetic ring.

FIG. 9a is an isometric exploded view of a magnetic cylindrical coil assembly.

FIG. 9b is an isometric view of the assembled magnetic cylindrical coil assembly of FIG. 9a.

FIG. 9c is a longitudinal section view of the assembled magnetic cylindrical coil assembly of FIG. 9a positioned within a motor/generator assembly.

FIG. 9d is a longitudinal section view of the assembled magnetic cylindrical coil assembly of FIG. 9a within the motor/generator assembly of FIG. 9c showing a brush system electrically coupled to various coils of the magnetic cylindrical coil assembly.

FIG. 10a is a section view of an alternative motor/generator assembly when a coil segment is not in an energized state.

FIG. 10b is a section view of the motor/generator assembly of FIG. 10a when the coil segment is in an energized state.

FIG. 11a is an isometric view of an alternative assembled magnetic cylindrical coil assembly.

FIG. 11b is a longitudinal isometric section view of the assembled magnetic cylindrical coil assembly of FIG. 10a positioned within an alternative motor/generator assembly.

5

FIG. 11c is a longitudinal section view of the assembled magnetic cylindrical coil assembly of FIG. 10a within the motor/generator assembly of FIG. 10b.

FIG. 11d is a longitudinal section view of the assembled magnetic cylindrical coil assembly of FIG. 10a within the motor/generator assembly of FIG. 10b showing a brush system electrically coupled to various coils of the magnetic cylindrical coil assembly.

FIG. 12 is a longitudinal section view of an alternative magnetic cylindrical coil assembly positioned within a motor/generator assembly.

FIGS. 13a and 13b illustrate a hybrid electromagnet magnet assembly which may be used in place of conventional magnets in the various magnetic cylinders discussed within this disclosure.

DETAILED DESCRIPTION

Specific examples of components, signals, messages, protocols, and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to limit the invention from that described in the claims. Well-known elements are presented without detailed description in order not to obscure the present invention in unnecessary detail. For the most part, details unnecessary to obtain a complete understanding of the present invention have been omitted inasmuch as such details are within the skills of persons of ordinary skill in the relevant art. Details regarding control circuitry, power supplies, or circuitry used to power certain components or elements described herein are omitted, as such details are within the skills of persons of ordinary skill in the relevant art.

When directions, such as upper, lower, top, bottom, clockwise, or counter-clockwise are discussed in this disclosure, such directions are meant to only supply reference directions for the illustrated figures and for orientation of components in the figures. The directions should not be read to imply actual directions used in any resulting invention or actual use. Under no circumstances, should such directions be read to limit or impart any meaning into the claims.

Most motors and generators used today require or produce a sinusoidal time varying voltage referred to as Alternating Current (AC). When Direct Current is utilized it must first be inverted and pulsed to replicate an AC waveform to produce the desired current or mechanical output. Certain embodiments of the present invention neither produces nor utilizes Alternating Current but instead directly produces or utilizes a non sinusoidal Direct Current without the need for rectification or commutation. This results in the elimination of Alternating Current Losses and results in a more efficient utilization of input or output power. However, certain aspects of the invention may accept any rectified A/C current and thus may be "blind" to input power supply phasing. Thus, simple rectified single phase, two phase, three phase power, etc. are all acceptable for input power depending on the configuration.

Turning now to FIG. 1, there is a cross-sectional view of one embodiment of a toroidal magnetic cylinder 100 illustrating representative planar magnetic flux paths 101 within and around the cylinder. These are representative illustrations; actual flux paths are dependent on the material design and specific configuration of the magnets within the cylinder. The magnetic cylinder 100 comprises an outer cylinder wall of 102 and an inner cylinder wall 104. The outer cylinder wall 102 and inner cylinder wall 104 may be made with a plurality of magnets. In a lateral section view, such as illustrated in FIG. 1, it can be seen that the outer cylinder wall 102 is comprised of a plurality of magnets 106, comprising indi-

6

vidual magnets, such as magnets 106a, 106b, 106c, etc. Similarly, the inner cylinder wall 104 may be comprised with a plurality of magnets 108, comprising individual magnets 108a, 108b, etc. It should be noted that only one polarity of the magnets are utilized within (or facing into) the magnetic cylinder or magnet assembly.

In certain embodiments, there may be a central iron core 110 positioned between the outer wall 102 and the inner wall 104, however other core materials maybe used when design considerations such as strength, reduction of eddy currents, cooling channels, etc. are considered.

In certain embodiments, the plurality of magnets 106 and magnets 108 may be made of out any suitable magnetic material, such as: neodymium, Alnico alloys, ceramic permanent magnets, or electromagnets. In certain embodiments, each magnet 106a or 108a in the respective plurality of magnets has the dimensions of 1"x1"x1." The exact number of magnets or electromagnets will be dependent on the required magnetic field strength or mechanical configuration. The illustrated embodiment is only one way of arranging the magnets, based on certain commercially available magnets. Other arrangements are possible—especially if magnets are manufactured for this specific purpose.

When the plurality of magnets 106 and 108 are arranged into the outer wall 102 and inner wall 104 to form the cylinder 100, the flux lines 101 will form particular patterns as represented in a conceptual manner by the flux lines illustrated in FIG. 1. The actual shape, direction, and orientation of the flux lines 101 depend on factors such as the use of an interior retaining ring, material composition and configuration. For example, the flux line 112a from the magnet 106a on the exterior wall tends to flow from the north pole of the magnet in a perpendicular manner from the face of the magnet around the cylinder 100, and back through an open end 114, then flow through the iron core 110 and back to the face of the magnet 106a containing its south pole. Similarly, the flux line 112b from the magnet 106b on the exterior wall 102 tends to flow from the north pole of the magnet in a perpendicular manner from the face of the magnet around the cylinder 100, and back through the open end 114, then flow through the iron core 110 and back to the face of the magnet 106b containing its south pole. Although only a few flux lines 112 are illustrated for purposes of clarity, each successive magnet in the plurality of magnets will produce similar flux lines. Thus, the magnetic flux forces for each successive magnet in the plurality of magnets 106 tend to follow these illustrative flux lines or patterns 112 for each successive magnetic disc in the plurality of magnets 106 until the magnets at the open ends 114 or 116 of the magnetic cylinder 100 are reached.

Magnets on the opposing side of the cylinder 100, such as magnet 106c tend to generate flux lines 112c from the magnet 106c on the exterior wall 102 which tends to flow from the north pole of the magnet in a perpendicular manner from the face of the magnet around the cylinder 100, and back through an opposing open end 116, then flow through the iron core 110 and back to the face of the magnet 106c containing its south pole. Although only a few flux lines 112 on the opposing side of the cylinder 100 are illustrated for purposes of clarity, each successive magnet in the plurality of magnets will produce similar flux lines.

In certain embodiments, the interior wall 104 also produces flux lines 118. For instance, the flux line 118a from the magnet 108a on the interior wall 104 tends to flow from the north pole in a perpendicular manner from the face of the magnet, around the interior wall 104 via the iron core 110, and back through the radial center of the interior wall 104 to the face of the magnet 108a containing its south pole. Similarly,

the flux line **118b** from the magnet **108b** on the interior wall **104** tends to flow from the north pole in a perpendicular manner from the face of the magnet, around the interior wall **104** via the iron core **110**, and back through the radial center of the interior wall **104**, then back to the face of the magnet **108b** containing its south pole.

The magnetic flux forces for each successive magnet in the plurality of magnets **108** tend to follow these illustrative flux lines or patterns **118** for each successive magnet in the plurality of magnets **108** until the open ends **114** or **116** of the magnetic cylinder **100** are reached. Thus, the flux produced by the magnets of the interior wall **104** of the cylinder **100** have an unobstructed path to exit through the center of the cylinder and return to its opposing pole on the exterior of the cylinder.

In some embodiments, the magnetic flux lines **112** and **118** will tend to develop a stacking effect and the configuration of the exterior magnetic cylinder manipulates the flux lines **101** of the magnets in the magnetic cylinder **100** such that most or all of the flux lines **110** flows out of the open ends **114** and **116** of the cylinder **100**.

In conventional configurations, the opposing poles of the magnets are usually aligned longitudinally. Thus, the field flux lines will "hug" or closely follow the surface of the magnets. So, when using conventional power generating/utilization equipment, the clearances must usually be extremely tight in order to be able to act on these lines of force. By aligning like magnetic poles radially with respect to the center **120** of the cylinder **100**, the magnetic flux lines **112** and **118** tend to stack up as they pass through the center of the magnetic cylinder **110** and radiate perpendicularly from the surface of the magnets. This configuration allows for greater tolerances between coils and the magnetic cylinder **100**.

In certain embodiments, the iron core **110** is positioned concentrically about the center **120** of the magnetic cylinder **100** such that the iron core is an equidistant radially from the interior wall **104**, generating a representative flux pattern **101** as illustrated in FIG. 1. The flux fields or lines are drawn to the iron core **110** and compressed as it approaches the iron core. The flux fields may then established what can be visualized as a series of "flux walls" surrounding the iron core which extend throughout the cylinder and the exit points.

Turning now to FIG. 2a, there is presented is a conceptual isometric view of the toroidal magnetic cylinder **100** having the central iron core **110** positioned within the magnetic cylinder. FIG. 2b is a detailed partial view of the toroidal magnetic cylinder **100** illustrating the planar magnetic fields or flux walls **122** generated within the interior cavity **124** of the magnetic cylinder **100** in conjunction with the iron core **110**. These are representative illustrations; the actual flux walls **122** are dependent on the material design and configuration.

The cylinder **100** as presented in FIGS. 1, 2a and 2b have been conceptualized to illustrate the basic flux lines or paths of a partial magnetic cylinder with an iron core concentrically located in a hollow portion of its walls. From a practical perspective, a core or rotor assembly may position the core **110** within the magnetic cylinder **100**.

Turning now to FIG. 3, there is presented an isometric view of a one embodiment of an assembly **130** comprising an iron core **132**, a rotor hub **134** and shaft **136**. The iron core **132** is similar to the core **110** discussed above. The iron core **132** and the rotor hub **134** are fastened to a shaft **136** using conventional fastening methods known in the art. In certain embodiments the rotor hub **134** may be composed of non-ferrous materials for example, to eliminate the production of eddy currents. When assembled with the magnetic cylinder **100**, a transverse slot (not shown) in the inner wall **104** of the mag-

netic cylinder (not shown in FIG. 3) allows the core **132** and a portion of the rotor hub **134** to extend through the inner wall **104** of the magnetic cylinder **100** and into the interior cavity **124** (See FIG. 2b).

In certain embodiments, leakage flux through the transverse slot may be reduced or eliminated by embedding a series or plurality of magnets **138** in a periphery of the rotor hub **134**. The plurality of magnets **138** may be oriented similar to the cylinder magnets **106** of the cylinder **100** (not shown in FIG. 3). In certain embodiments, the plurality of magnets **138** will move with the rotor assembly **130**.

In other embodiments the iron core **132** may consist of two or more segments **140a** and **140b** which may be fastened together to form a complete ring or core. This configuration may have the benefit of allowing a plurality of coils to be built on conventional forms then added to ring segments.

FIG. 4 illustrates an isometric view of the rotor assembly **130** where the core **132** comprises the core segment **140a** and the core segment **140b**. A single coil **142a** is positioned about the core segment **140a**. In certain embodiments, there may be a plurality of coils **142** as illustrated in FIG. 5.

FIG. 5 is a lateral cross-sectional view of one embodiment of an electric motor/generator assembly **150** which incorporates the magnetic cylinder **100** and the rotor hub **134**. FIG. 6 is a longitudinal cross-sectional view of the electric motor/generator assembly **150**. The motor/generator assembly **150** may use components similar to the components discussed above, such as the magnetic cylinder **100** and the rotor hub **134**. FIG. 7 is a lateral cross-sectional view of one embodiment of an electric motor/generator assembly **150** illustrating additional detail regarding the current paths between individual coils in the plurality of coils **142**. The coils illustrated in FIG. 7 are connected in series but any combination of series or parallel connections are possible. Additional brush locations may be added depending on design needs and criteria.

In the illustrative embodiment, the motor/generator assembly **150** has a longitudinal shaft **152**. In certain embodiments, the longitudinal shaft **152** may be made from an iron or a ferrite compound with similar magnetic properties to iron. In some embodiments, the ferrite compound or powder may be suspended in a viscous material, such as an insulating liquid, a lubricant, motor oil, gel, or mineral oil.

In certain embodiments, there may be an outer casing or housing **154** which provides structural support for the magnetic cylinder **100** and the longitudinal shaft **152**. In certain embodiments, the housing **154** may be formed from any material, alloy, or compound having the required structural strength. In certain embodiments, non-ferrous materials may be used. In some embodiments, external bearings **156** (FIG. 6) may be used to reduce the friction between the longitudinal shaft **152** and the housing **154** or a similar supporting structure. In certain embodiments, the housing **154** may be coupled to a base **158** to provide for structural support for the housing **154**.

As described with respect to FIGS. 1, 2a and 2b, the toroidal magnetic cylinder **100** may comprise a plurality of exterior magnets **106** forming the exterior wall **102**, a plurality of interior magnets **108** forming the interior wall **104**. Additionally, there may first side wall **170** and an opposing side wall **172** which include a plurality of side exterior magnets **168** (see FIGS. 5 and 6).

In certain embodiments, the core **132** as discussed above is positioned concentrically about a longitudinal axis **176** and within the interior cavity **124** of the magnetic cylinder **100**. As described above, a transverse slot **162** formed within the interior wall **104** of the magnetic cylinder **100** allows a portion of the rotor hub **134** to be positioned within the interior

cavity **124**. The rotor hub **134** is also coupled to the core **132** which is also positioned within the interior cavity **124** of the magnetic cylinder **100**.

A plurality of coils **148**, such as coil **148a** are positioned radially about the core **132** to form a coil assembly **182**. Each individual coil **178a** in the coil assembly **182** may be made from a conductive material, such as copper (or a similar alloy) wire and may be constructed using conventional winding techniques known in the art. In certain embodiments, the individual coils **178a** may be essentially cylindrical in shape being wound around a coil core (not shown) having a center opening sized to allow the individual coil **178a** to be secured to the core **132**.

Although a particular number of coils in the plurality of coils **142** are illustrated in FIGS. **5** and **7**, depending on the power requirements of the motor/generator assembly, any number of coils could be used to assemble the coil assembly **182**.

In certain embodiments, as illustrated in FIG. **6** and FIG. **7**, a plurality of slip ring segments **184** electrically connect the individual coils **142a** in the coil assembly **182** in series to each other. Other configurations of coil connections, slip rings and brush injection/pickup points may be utilized. For example, other embodiments may use two non-segmented slip rings and the coils in parallel connection to each other.

In some embodiments, the slip ring segments **184** are in electrical communication with a current source via a plurality of brushes **186** and **188** (FIG. **6**) which may also be positioned within the casing **154** to provide current to the plurality of coils **142** in the coil assembly **182**. In certain embodiments, the brush **186** may be a positive brush and the brush **188** may be the negative brush. In certain embodiments, inductive coupling may also be used to transfer power to the coils or vice versa.

When in the "motor mode," electric power is applied to power terminals **190** and **192**, certain coils in the plurality of coils **142** move through the magnetic cylinder **100** and only "see" "flux walls" similar to the flux walls discussed above in reference to FIG. **2b**. The plurality of coils **142** are not substantially affected by the direction of flux within the core **132**, thus the plurality of coils move according to the "right hand rule" throughout the cylinder **100**. However during the short period of time that certain coils of the plurality of coils **142** are out of the magnetic cylinder **100** itself and traveling through the open segment **194**, it is possible they can also contribute to the torque being produced. During this transition period, the flux is now leaving the core **132** on its path to the external walls of the magnetic cylinder **100** which is in the opposite direction to the flux forces within the magnetic cylinder, thus each coil in the plurality of coils **142** has to be supplied with a reverse polarity to contribute torque.

At the contact area for the negative brush **188**, the current is divided into two paths, one path is back through the plurality of coils within the magnetic cylinder **100** itself, the other path is routed through the coils positioned in the open segment **194**. Thus, the individual coils in the plurality of coils **142** are automatically provided with the correct polarity as illustrated in FIG. **7**.

In the generator mode, when the plurality of coils **142** move through the magnetic cylinder **100** as a result of the shaft **152** being rotated, the coils within the magnetic cylinder only see the "flux walls" (as discussed in reference to FIG. **2b**). They may not be affected by the direction of flux within the core, thus the coils produce power throughout their travel through the magnetic cylinder **100**. However during the short period of time they are out of the cylinder **100** itself and traveling through the open segment **194**, it is possible the coils can also

contribute to the power being produced. During this transition period when the coils are in the open segment **194**, the flux is now leaving the iron core **132** on its path to the external walls **102**, **104**, **170** and **172** of the magnetic cylinder **100** which is, however in the opposite direction to the flux forces within the magnetic cylinder. Thus, the coil assembly **182** can also produce usable power which can be utilized depending on design needs.

Should it be desired to remove the open segment coil from the circuit, a diode rectifier may be added to one side of each coil to limit current flow to a specific direction.

As is well known, almost all conventional magnets have magnetic poles. Magnetic poles are typically either of two regions of a magnet, typically designated north and south, where the magnetic field or flux density is strongest. FIGS. **8a** through **8d** illustrate the combinations of typical permanent magnets that may be utilized in magnetic rings or cylinders to create the concentrated flux densities of one magnetic pole (such as the north or south pole). Such magnets may be traditional magnets, electro-magnets, or an electro-permanent magnet hybrid discussed later in this application. Additionally, iron, iron powder or other magnetic material may be added to the cylinder core area for increased magnetic flux densities and concentrations (not shown).

Rather than using a magnetic cylinder **100** as described above, an alternative magnetic ring or cylinder **200** can be made of a single row of magnets, such as illustrated in FIG. **8a**. As illustrated in FIG. **8a**, all of the like or similar poles (e.g. south poles) of the plurality of magnets **202**, such as magnet **202a** face inward. Such a magnetic ring **200** could be used in a motor or generator, but the strength of the magnetic field or intensity of the flux field (and therefore the motor or generator) would primarily depend on the strength of the individual magnets **202a** in the plurality of magnets **202**.

FIG. **8b** is an isometric illustration of a portion **210** of a magnetic ring, where each portion **210** comprises a magnet **212** and a magnet **214**. Positioning the magnet **212** and magnet **214** so that a magnetic ring has a cross sectional shape of a "V" as illustrated in FIG. **8b** and where the like poles face each other increases the strength of the magnetic field or flux density at the throat even if the strength of the individual magnets remain the same. For purposes of this disclosure, such a configuration may be known as a "2x" magnet cylinder assembly, where the term "x" indicates the approximate increase in flux density per magnet surface area (and not necessarily the number of magnets used). Such a configuration may increase the flux density approximately two times at the selected pole exit area **211**. Collapsing or compressing the "V" further concentrates the flux density but at the expense of a smaller exit area **211**.

FIG. **8c** is an isometric illustration of a portion **220** of a magnetic ring, where each portion **220** comprises a magnet **222**, a magnet **224**, and a magnet **226**. Positioning the magnet **222**, the magnet **224**, and the magnet **226** so that a magnetic ring has a cross sectional shape of a "U" as illustrated in FIG. **8c** and where the like poles face of each magnet faces inward increases the strength of the magnetic field or flux density even if the strength of the individual magnets remain the same. For purposes of this disclosure, such a configuration may be known as a "3x" conceptual magnet cylinder assembly. Such a configuration may increase the flux density approximately three times at the selected pole exit area **221**. Collapsing or compressing the "U" (i.e., moving magnet **224** towards magnet **222**) further concentrates the flux density but at the expense of a smaller exit area **221**.

FIG. **8d** is an isometric illustration of a portion **230** of a magnetic ring, where each portion **230** comprises a magnet

11

232, a magnet 234, a magnet 236, a magnet 238, and a magnet 240 (not visible in FIG. 8d). Positioning the magnet 232 opposing the magnet 234 so that their like poles face each other and positioning the magnet 236 opposing the magnet 238 so that their like poles face each other. In other words, all of the south poles of the magnets 236 through 238 face inward. Furthermore, a magnet 240 is positioned on the back face of the "tube" formed by the magnets 232 to 238 to create an open box shape or cube as illustrated in FIG. 8d. For purposes of this disclosure, such a configuration may be known as a "5x" conceptual magnet cylinder assembly. Such a configuration may increase the flux density approximately five times at the selected pole exit area 231. Collapsing or compressing the box area (e.g., moving the magnets 236 towards magnet 238) further concentrates the flux density but at the expense of a smaller exit area 231.

For brevity and clarity, a description of those parts or components which are identical or similar to those described above will not be repeated here. Reference should be made to the foregoing paragraphs with the following description to arrive at a complete understanding of alternative embodiments.

Turning now to FIGS. 9a through 9d, there is presented an alternative embodiment or a 3x design which concentrates the magnetic field or flux lines to improve the efficiency of the motor or generator. FIG. 9a is an isometric exploded view of a magnetic cylindrical coil assembly 300. FIG. 9b is an isometric view of the assembled magnetic cylindrical coil assembly 300. FIG. 9c is a longitudinal section view of the assembled magnetic cylindrical coil assembly 300 within a motor/generator assembly 350. FIG. 9d is a longitudinal section view of the assembled magnetic cylindrical coil assembly 300 within a motor/generator assembly 350 showing a brush system electrically coupled to various coils of the magnetic cylindrical coil assembly. Although four brushes per toroid cylinder are shown, the actual number of brushes depend on well known engineering factors, such as wear and current carrying capacity.

Turning now to FIGS. 9a and 9b, there is an enhanced flux toroidal core magnetic cylinder assembly 300. In some aspects, many of these components of the cylinder assembly 300 are assembled utilizing the enhanced magnetic cylinder concepts as described above. Note that only one pole (i.e., either North or South) is used and concentrated throughout the length and breadth of the magnetic cylinder 300.

In certain embodiments, a conductor wrapped coil assembly 310 comprises a core 312 which may be formed of iron, iron powder composite or other magnetic/non-magnetic core material. A conductive material 314, such as copper wire is wrapped around the core 312 to form one or more coils. Thus, the coil assembly 310 may consist of one or more coil segments. Especially in brushless designs, multiple coil segments allows speed control by selectively connecting coil segments in differing combinations of series and parallel connections without changing the system supply voltage. For purposes of example, certain embodiments of the coil assembly 310 may comprise twenty four ("24") coil segments which allows multiple possible combinations of series-parallel connections resulting in multiple output speeds or output power. Where a continuously variable speed or torque requirement are required, input voltages may be adjusted accordingly and if needed, in combination with simple relaying or switched step control of the series-parallel connections between the coil segments. The coil assembly 310 is generally ring shape which allows an interior longitudinal magnetic cylinder 315 to slip through the coil assembly's central aperture 316.

12

As illustrated, the interior magnetic cylinder 315 comprises a series or plurality of magnets 318 where the north poles face radially outward and transverse to the longitudinal axis 302. Thus, when assembled the north poles of the plurality of magnets 318 would face the core 312 of the coil assembly 310. A first side or end magnetic ring assembly 320 is positioned next to the coil assembly 310. In certain embodiments the first side magnetic ring assembly 320 comprises a plurality of magnets 322 arranged in a radial pattern where the poles of each magnet 322a in the plurality of magnets are generally aligned in a parallel fashion with a longitudinal axis 302. As illustrated the north poles of the plurality of magnets 322 face inward toward the core 312 or the coil assembly 310.

In certain embodiments, a second side or end magnetic ring assembly 330 comprises a plurality of magnets 332 arranged in a radial pattern where the poles of each magnet 332a in the plurality of magnets are generally aligned in a parallel fashion with the longitudinal axis 302. As illustrated the north poles of the plurality of magnets 332 face inward toward the coil assembly 310.

When assembled, it is apparent from discussion regarding FIGS. 8a through 8d, that the coil assembly 300 uses a 3x flux concentrator design to concentrate the flux force intensity or magnetic fields.

FIG. 9c is a longitudinal cross-sectional view of one embodiment of an electric motor/generator assembly 350 which incorporates the magnetic cylinder 300. The motor/generator assembly 350 may use components similar to the components discussed above, such as the magnetic cylinder 100 and the rotor hub 134.

In the illustrative embodiment, the motor/generator assembly 350 has a longitudinal shaft 352. In certain embodiments, the longitudinal shaft 352 may be made from an iron, steel, or a ferrite compound with similar magnetic properties to iron. In certain embodiments, the longitudinal shaft 352 may include a ferrite compound or powder. In some embodiments, the ferrite compound or powder may be suspended in a viscous material, such as an insulating liquid, a lubricant, motor oil, gel, or mineral oil to reduce or eliminate eddy currents and magnetic hysteresis.

In certain embodiments, there may be an outer casing or housing 354 which provides structural support for the magnetic cylinder 300 and the longitudinal shaft 352. In certain embodiments, the housing 354 may be formed from any material, alloy, or compound having the required structural strength. In certain embodiments, non-ferrous materials may be used. In some embodiments, external bearings (not shown) may be used to reduce the friction between the longitudinal shaft 352 and the housing 354 or a similar supporting structure. In certain embodiments, the housing 354 may be coupled to a base (not shown) to provide for structural support for the housing 354.

As illustrated in FIG. 9c, the magnetic cylinder 300 may be a 3x brushless assembly in that the magnet assembly (e.g., the magnetic longitudinal cylinder 315, the first side magnetic ring 320, and the second side magnetic 330) acts as the rotor with the toroidal coil assembly 310 stationary. This configuration has the advantage of using coil segments whose conductor leads can be brought to a single location (not shown) allowing stepped speed control by simple switching series-parallel combinations in combination with varying voltage inputs where stepless control of motor/generator outputs are desired. A connecting hub 317 couples the magnetic cylinder 315 to the shaft 302 in a conventional manner.

FIG. 9d illustrates the magnetic cylinder 300 as a 3x concentrated brushed "side wall" brush assembly. This assembly may be easily incorporated into a modular assembly 500

13

illustrated in FIGS. 11a through 11d below. In certain embodiments, the modular assembly 500 may be a bolt up modular assembly which allows greater flexibility in selecting differing mechanical or electrical outputs without major design changes. Engineering needs and design consideration will determine the maximal numbers of magnetic cylinder and coils assemblies.

Turning now to FIGS. 10a and 10b, there is presented an alternative embodiment or a 3x design which concentrates magnetic fields or flux lines 401 to improve the efficiency of a motor or generator 450. FIG. 10a is a longitudinal section view of the assembled magnetic cylindrical coil assembly 400 within the motor/generator assembly 450 where a coil segment 410a is not in an energized state. FIG. 10b is a longitudinal section view of the motor/generator assembly 450 when the coil segment 410a is in an energized state (i.e., current/voltage moving through the conductive material 414).

The enhanced flux toroidal core magnetic cylinder assembly 400 is similar to the core magnetic cylinder assembly 300 except that the interior parallel magnetic cylinder 315 is positioned on the outside of the side magnets ring assemblies 420 and 430.

In certain embodiments, a conductor wrapped coil assembly 410 comprises a core 412 which may be formed of iron, iron powder composite or other magnetic/non-magnetic core material similar to the core 312 discussed above. A conductive material 414, similar to the conductive material 314, is wrapped around the core 412 to form one or more coils or coil segments such as coil segment 410a. Thus, the coil assembly 410 may consist of one or more coil segments as described above in reference to the coil assembly 310.

The coil assembly 410 is generally ring shape which allows a connecting hub 417 to couple the coil assembly 410 to a longitudinal shaft 452. In certain embodiments, the connecting hub may be coupled to slip rings (not shown) or bushings 419.

As illustrated, the exterior magnetic cylinder 415 comprises a series or plurality of magnets 418 where the north poles face radially inward towards the core 412 and the longitudinal axis 402. A first side magnetic ring assembly 420 is positioned next to the coil assembly 410. In certain embodiments, the first side magnetic ring assembly 420 comprises a plurality of magnets 422 arranged in a radial pattern where the poles of each magnet 422a in the plurality of magnets are generally aligned in a parallel fashion with a longitudinal axis 402. As illustrated the north poles of the plurality of magnets 422 face inward toward the core 412.

In certain embodiments a second side magnetic ring assembly 430 comprises a plurality of magnets 432 arranged in a radial pattern where the poles of each magnet 432a in the plurality of magnets are generally aligned in a parallel fashion with the longitudinal axis 402. As illustrated the north poles of the plurality of magnets 432 face inward toward the core 412.

In the illustrative embodiment, the motor/generator assembly 450 has a longitudinal shaft 452. In certain embodiments, the longitudinal shaft 452 may be similar to the longitudinal shaft 352 discussed above.

In certain embodiments, there may be an outer casing or housing 454 (similar to housing 354 discussed above) which provides structural support for the coil assembly 410 and the longitudinal shaft 452. In some embodiments, external bearings (not shown) may be used to reduce the friction between the longitudinal shaft 452 and the housing 454 or a similar supporting structure.

As illustrated in FIGS. 10a and 10b, the magnetic cylinder 400 may be a 3x brushless assembly in that the magnet cyl-

14

inder assembly 400 (e.g., the exterior magnetic ring 414, the first side magnetic ring 420, and the second side magnetic 430) acts as the stator with the toroidal coil assembly 410 acting as a rotor.

FIG. 10a illustrates the representative flux paths in a 3x magnetic cylinder assembly section prior to energization of the coils. When a current is established in the coil segment 410a, the permanent magnet flux lines 401 of FIG. 10a are forced outside the coil segment 410a and are compressed in the remaining space between the magnetic rings and the core or coil segment 410a as illustrated in FIG. 10b. A Lorentz force is then imparted on the rotor causing rotation in the case of a motor and induced current flow in the case of a generator. The force imparted or the voltage/current flow established is indicated by the Lorentz force calculations.

In a motor, force is equal to flux density in Tesla times the amperage times the conductor length in meters. In a generator voltage is equal to flux density in Tesla times velocity times times conductor length in meters. In all configurations presented in this application these basic calculations are utilized.

Turning now to FIGS. 11a through 11d, there is presented an alternative modular embodiment where each module uses a 3x design which concentrates the magnetic field or flux lines to improve the efficiency of the motor or generator. FIG. 11a is an isometric view of the assembled magnetic cylindrical coil assembly 500. FIG. 11b is a longitudinal isometric section view of the assembled magnetic cylindrical coil assembly 500 within a motor/generator assembly 550. FIG. 11c is a longitudinal section view of the assembled magnetic cylindrical coil assembly 500 within a motor/generator assembly 550. FIG. 11d is a longitudinal section view of the assembled magnetic cylindrical coil assembly 500 within a motor/generator assembly 550 showing an exemplary brush system electrically coupled to various coils of the magnetic cylindrical coil assembly.

Turning now to FIGS. 11a and 11b, there is an enhanced flux toroidal core magnetic cylinder assembly 500. In some aspects, many of these components of the cylinder assembly 500 are assembled utilizing the enhanced magnetic cylinder concepts as described above. The magnetic assembly 500 is essentially three magnetic cylinders 100 (discussed above) assembled longitudinally as a single cylinder assembly (with certain polarities reversed as explained below) and on a common shaft.

In certain embodiments, conductor wrapped coil assemblies 510a through 510c include cores 512a through 512c similar to the core 312 discussed above. The cores 512a through 512c may be formed of iron, iron powder composite or other magnetic/non-magnetic core material. Conductive materials 514a through 514c, such as copper wire are individually wrapped around the cores 512a, the core 512b, and the core 512c to form one or more coil segments for each coil assembly 512a through 512c. As discussed above, multiple coil segments in each coil assembly 510a through 510c allows speed control by selectively connecting coil segments in differing combinations of series and parallel connections without changing the system supply voltage.

The coil assemblies 510a through 510c are generally ring shape which allows for interior magnetic cylinders 514a through 514c to be positioned annularly with respect to a longitudinal axis 502. A plurality of hubs, such as hub 516a through 516c couple a longitudinal shaft 552 to the interior magnetic cylinders 515a through 515c.

As illustrated, the interior magnetic cylinders 515a through 515c each comprise a series or plurality of magnets 518 positioned such that their magnetic poles are radially aligned perpendicular to the longitudinal axis 502. A first end mag-

15

netic ring assembly **520** is positioned next to the coil assembly **510a**. In certain embodiments, the first end magnetic ring assembly **520** comprises a plurality of magnets **522** arranged in a radial pattern where the poles of each magnet in the plurality of magnets are generally aligned in a parallel fashion with a longitudinal axis **502** (similar to the ring assembly **320** discussed above). As illustrated, the north poles of the plurality of magnets **522** face inward toward the core **512a**.

In certain embodiments a second end magnetic ring assembly **530** comprises a plurality of magnets **532** arranged in a radial pattern where the poles of each magnet **532a** in the plurality of magnets are generally aligned in a parallel fashion with the longitudinal axis **502**. As illustrated, in FIGS. **11c** and **11d**, the north poles of the plurality of magnets **532** face inward toward the core **512c**.

As illustrated in FIGS. **11c** and **11d**, the magnetic cylinder **500** may include three “magnetic cylinders” **500a**, **500b**, and **500c** spaced longitudinally from each other and sharing the same shaft **552** and longitudinal axis **502**. In the embodiment of the magnetic cylinder **500**, the individual magnetic cylinders **500a**, **500b**, and **500c** alternate magnetic polarities. For instance, the north pole of magnet **515a** faces outward towards the core **512a**. However, the north pole of the magnet **515b** faces inward away from the core **512b**. Similarly, the north pole of magnet **515c** faces outward towards the core **512c**. This pattern would continue if more individual magnetic cylinders were added to the magnetic cylinder assembly **500**.

In other words, the space filled by the core **512a** for the individual magnetic cylinder **500a** has a magnetic force filled with a “north pole” polarity from the positioning of the magnets **522**, the magnets **515a**, and the magnets of the magnetic ring **524**. On the other hand, the space filled by the core **512b** for the individual magnetic cylinder **500b** has a magnetic force filled with a “south pole” polarity from the positioning of the magnets of the magnetic ring **524**, the magnets **515b**, and the magnets of the magnetic ring **526**. The space filled by the core **512c** for the individual magnetic cylinder **500c** has a magnetic force filled with a “north pole” polarity from the positioning of the magnets from the magnetic ring **526**, the magnets **515c**, and the magnets of the magnetic ring **532**.

In certain embodiments, the longitudinal shaft **552** may be made from an iron, steel, or a ferrite compound with similar magnetic properties to iron. In certain embodiments, the longitudinal shaft **552** may include a ferrite compound or powder. In some embodiments, the ferrite compound or powder may be suspended in a viscous material, such as an insulating liquid, a lubricant, motor oil, gel, or mineral oil to reduce or eliminate eddy currents and magnetic hysteresis.

In certain embodiments, there may be an outer casing or housing **554** which provides structural support for the magnetic cylinder **500** and the longitudinal shaft **552**. In certain embodiments, the housing **554** may be formed from any material, alloy, or compound having the required structural strength. In certain embodiments, non-ferrous materials may be used. In some embodiments, external bearings (not shown) may be used to reduce the friction between the longitudinal shaft **552** and the housing **554** or a similar supporting structure. In certain embodiments, the housing **554** may be coupled to a base (not shown) to provide for structural support for the housing **554**.

In this example, the magnetic cylinders **500a** through **500c** include a 3x concentration and brushless assembly in that the magnet assembly (e.g., the magnetic ring or cylinder **515**, the first side magnetic ring **520**, and the second side magnetic **530**) acts as the rotor with the toroidal coil assembly **510** stationary. This configuration has the advantage of using coil

16

segments whose conductor leads can be brought to a single location (not shown) allowing stepped speed control by simple switching series-parallel combinations in combination with varying voltage inputs where stepless control of motor/generator outputs are desired.

FIG. **12** is a longitudinal cross-sectional view of one embodiment of an electric motor/generator assembly **650** which incorporates an enhanced flux magnetic cylinder **600**. The motor/generator assembly **650** may use components similar to the components discussed above, such as coil assembly **610**. In some aspects, many of these components of the magnetic cylinder assembly **600** and the motor/generator assembly **650** are assembled utilizing the enhanced magnetic cylinder concepts as described above.

In certain embodiments, the conductor wrapped coil assembly **610** comprises a core **612** similar to the core **312** discussed above. A conductive material **614**, such as copper wire is wrapped around the core **612** to form one or more coil segments **610a**. The coil assembly **610** is generally ring shape and may be coupled to a connecting hub or sling ring assembly **617** which may in turn be coupled to a shaft **652**.

As illustrated, the enhanced flux toroidal magnetic cylinder assembly **600** comprises three U-shaped magnetic cylinders **680**, **682** and **684** where the open end face of each U shaped cylinder faces the core **612** or the coil assembly **610**. Each of the U-shaped magnetic cylinders are comprised with a series or plurality of magnets **618** where the north poles of each magnet faces inward towards the “U” space. Thus when assembled, the north poles of the plurality of magnets **618** faces the core **612** to concentrate the magnetic fields of the magnets.

The coil assembly **600** uses a 9x flux concentrator design (three 3x concentrators). Thus, the assembled **650** motor/generator has a magnetic concentration of 9x and uses a typical DC brushes **619** (although four are shown, any number may be used depending on the engineering factors) to impart or collect the current. In this particular embodiment, the toroidal coil assembly **610** acts as the rotor which is connected to a slip ring assembly **642**. The 9x magnet cylinder or ring assembly acts as the stator. The greater flux density acting on the conductors increases the Lorentz outputs in motor or generator mode.

In the illustrative embodiment, the motor/generator assembly **650** has a longitudinal shaft **652**, similar to the shaft **352** discussed above.

In certain embodiments, there may be an outer casing or housing **654** which provides structural support for the magnetic cylinder **600** and the longitudinal shaft **652**.

FIGS. **13a** and **13b** illustrate a hybrid electromagnet magnet assembly **700** which may be incorporated in certain aspects of the above magnetic cylinders to concentrate the magnetic fields. Additionally, iron cores or similar materials may also be used with the magnetic cylinders to concentrate the magnetic fields as described above.

In certain embodiments, the magnet assembly **700** comprises at least two or more commercially available permanent magnets **710** and **712** positioned on either end of an iron core **714**. In the illustrated embodiment a cylinder shape has been selected but any shape may be constructed in any suitable configuration.

FIG. **13a** illustrates conceptual flux lines **716** of the hybrid magnet assembly **700**. One skilled in the art may see that though some of the aligned magnetic domains will contribute to flux lines **716** exiting the permanent magnets pole faces, however, most will “leak” out of the core side walls **718**.

FIG. **13b** illustrates the hybrid magnet assembly **700** with a spirally wrapped a conductive material **720** carrying a cur-

17

rent. As illustrated, the conductor 720 confines and concentrates all the flux lines 716 to align any magnetic domains not aligned by the permanent magnets. This addition allows the creation of much stronger magnetic flux outputs at a lower ampere turn levels than conventional iron core coils.

Thus, such "hybrid" magnet assemblies can also be used to assist in the concentration of flux force lines in the magnetic cylinders discussed above.

In certain embodiments, there is an apparatus or system claims to produce voltage, for instance, there may be:

A system for generating DC electric voltage characterized by: a means for concentrating similarly polarized magnetic flux forces around a circumferential portion of a magnetic cylinder to create an area of magnetic concentration comprising a stacked plurality of similarly polarized magnetic flux forces, a means for coupling the coil segment to a longitudinal shaft such that as the longitudinal shaft rotates, the coil segment is moved into the area of concentration, a means for producing a voltage in the coil segment as the plurality of flux forces within the area of magnetic concentration are compressed, and a means for removing the voltage from the coil segment.

There may also be the above system further characterized by: a means for concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces wherein the additional area of magnetic concentration is radially positioned away from the area of magnetic concentration, a means for coupling the additional coil segment to a longitudinal shaft such that as the longitudinal shaft rotates, the additional coil segment is moved into the additional area of concentration, a means for producing an additional voltage in the additional coil segment as the plurality of flux forces within the area of magnetic concentration are compressed, and a means for removing the voltage from the coil segment.

There may also be the above systems wherein the system is further characterized by: a means for concentrating similarly polarized magnetic flux forces around a circumferential portion of an additional magnetic cylinder positioned longitudinally away from the magnetic cylinder to create an additional area of magnetic concentration within the additional magnetic cylinder comprising an additional stacked plurality of similarly polarized magnetic flux forces, a means for coupling an additional coil segment positioned within the additional cylinder to a longitudinal shaft such that as the longitudinal shaft rotates, the additional coil segment is moved into the additional area of concentration, a means for producing an additional current in the additional coil segment as the plurality of flux forces within the additional area of magnetic concentration are compressed, and a means for removing the additional voltage from the additional coil segment.

There may also be the above systems further characterized by: a means for concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the additional magnetic cylinder to create a second additional area of magnetic concentration comprising a second additional stacked plurality of similarly polarized magnetic flux forces wherein the second additional area of magnetic concentration is radially positioned away from the additional area of magnetic concentration, a means for coupling a second additional coil segment positioned within the additional cylinder to the longitudinal shaft such that as the longitudinal shaft rotates, the second additional coil segment is moved into the second additional area of concentration, a means for producing a second additional voltage in the second additional

18

coil segment as the plurality of flux forces within the second additional area of magnetic concentration are compressed, a means for removing the second additional voltage from the second additional coil segment.

Yet, there may also be a system or apparatus claims to produce mechanical power, for instance: A system for producing radial motion of a shaft, the system characterized by: a means for concentrating similarly polarized magnetic flux forces around a circumferential portion of a magnetic cylinder to create an area of magnetic concentration comprising a stacked plurality of similarly polarized magnetic flux forces, a means for radially moving a coil segment into the area of magnetic concentration, a means for applying a current to the coil segment to change the plurality of flux forces within the area of magnetic concentration, a means for creating a repulsive magnetic force on the coil segment to move the coil segment out of the area of magnetic concentration, and a means for coupling the coil segment to a longitudinal shaft such that as the coil segment moves out of the area of concentration, the shaft rotates in a radial manner.

There may also be the above system further characterized by: a means for concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces wherein the additional area of magnetic concentration is radially positioned away from the area of magnetic concentration, a means for radially moving an additional coil segment into the additional area of magnetic concentration, a means for applying an additional current to the additional coil segment to change the plurality of flux forces within the additional area of magnetic concentration, a means for creating an additional repulsive magnetic force on the additional coil segment to move the additional coil segment out of the additional area of concentration, and a means for coupling the additional coil segment to the longitudinal shaft such that as the additional coil segment moves out of the additional area of concentration, the additional coil segment contributes to the radial shaft rotation.

There may also be the above systems further characterized by: a means for concentrating similarly polarized magnetic flux forces around a circumferential portion of an additional magnetic cylinder positioned longitudinally away from the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces, a means for radially moving an additional coil segment into the additional area of magnetic concentration, a means for applying an additional current to the additional coil segment to change the additional plurality of flux forces within the additional area of magnetic concentration, a means for creating an additional repulsive magnetic force on the additional coil segment to move the additional coil segment out of the additional area of magnetic concentration, and a means for coupling the additional coil segment to the longitudinal shaft such that as the additional coil segment moves out of the additional area of concentration, the additional coil segment contributes to the radial shaft rotation.

There may also be the above systems further characterized by: a means for concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the additional magnetic cylinder to create a second additional area of magnetic concentration comprising a second additional stacked plurality of similarly polarized magnetic flux forces wherein the second additional area of magnetic concentration is radially positioned away from the additional area

19

of magnetic concentration, a means for radially moving a second additional coil segment into the second additional area of magnetic concentration, a means for applying a second additional current to the second additional coil segment to change the plurality of flux forces within the second additional area of magnetic concentration, a means for creating a second additional repulsive magnetic force on the second additional coil segment to move the second additional coil segment out of the second additional area of concentration, and a means for coupling the second additional coil segment to the longitudinal shaft such that as the second additional coil segment moves out of the second additional area of concentration, the second additional coil segment contributes to the radial shaft rotation.

Also disclosed are means of creating the area of concentration, which may include: the above systems further characterized by: a means for positioning a longitudinal magnet within the magnetic cylinder, such that a longitudinal has a longitudinal axis that is parallel to a longitudinal axis of the shaft and that the poles of the longitudinal magnet are transverse to the longitudinal axis of the shaft, a means for positioning a first transverse magnet within the magnetic cylinder, such that the poles of the of the first transverse magnet are parallel to the longitudinal axis of the shaft, a means for positioning a second transverse magnet within the magnetic cylinder, such that the poles of the of the second transverse magnet are parallel to the longitudinal axis of the shaft, such that similarly polarized magnet poles all face towards one area to produce the area of magnetic concentration.

There may also be the above system further characterized by: a first magnet positioned within the magnetic cylinder, a second magnet positioned within the magnetic cylinder, such that similarly polarized magnet poles of the first and second magnets face towards one area to produce the area of magnetic concentration.

There may also be the above systems further characterized by: wherein the means for concentrating is further characterized by a third magnet positioned within the magnetic cylinder, such that similarly polarized magnet poles of the first magnet, second magnet, and third magnet face towards one area to produce the area of magnetic concentration.

There may also be the above systems further characterized by: wherein the means for concentrating is further characterized by positioning an additional magnets within the magnetic cylinder, such that similarly polarized magnetic poles of the first magnet, the second magnet, and the third magnet, and the additional magnets are positioned such that the polarized magnetic poles of the plurality of additional magnets face towards one area to produce the area of magnetic concentration.

There may also be the above systems further characterized by: wherein the means for concentrating is further characterized by an electromagnetic magnet positioned within the magnetic cylinder to produce the area of magnetic concentration.

There may also be the above systems further characterized by: a first magnet positioned within the magnetic cylinder, a second magnet positioned within the magnetic cylinder, an iron core coupling the first magnet to the second magnet and positioned between the first magnet and the second magnet, conductive material wrapped around the iron core, and a means for applying a current to the conductive material to produce an area of magnetic concentration.

Also disclosed are method claims to produce DC voltage: such as a method of producing DC voltage, the method characterized by: concentrating similarly polarized magnetic flux forces around a circumferential portion of a magnetic cylinder

20

der to create an area of magnetic concentration comprising a stacked plurality of similarly polarized magnetic flux forces, coupling the coil segment to a longitudinal shaft such that as the longitudinal shaft rotates, the coil segment is moved into the area of concentration, producing a voltage in the coil segment as the plurality of flux forces within the area of magnetic concentration are compressed, removing the voltage from the coil segment.

The methods of the above claims further characterized by: concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces wherein the additional area of magnetic concentration is radially positioned away from the area of magnetic concentration, coupling the additional coil segment to a longitudinal shaft such that as the longitudinal shaft rotates, the additional coil segment is moved into the additional area of concentration, producing an additional voltage in the additional coil segment as the plurality of flux forces within the area of magnetic concentration are compressed, removing the voltage from the coil segment.

The methods of the above claims wherein the method is further characterized by: concentrating similarly polarized magnetic flux forces around a circumferential portion of an additional magnetic cylinder positioned longitudinally away from the magnetic cylinder to create an additional area of magnetic concentration within the additional magnetic cylinder comprising an additional stacked plurality of similarly polarized magnetic flux forces, coupling an additional coil segment positioned within the additional cylinder to a longitudinal shaft such that as the longitudinal shaft rotates, the additional coil segment is moved into the additional area of concentration, producing an additional voltage in the additional coil segment as the plurality of flux forces within the additional area of magnetic concentration are compressed, removing the additional voltage from the additional coil segment.

The methods of the above claims further characterized by: concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the additional magnetic cylinder to create an second additional area of magnetic concentration comprising a second additional stacked plurality of similarly polarized magnetic flux forces wherein the second additional area of magnetic concentration is radially positioned away from the additional area of magnetic concentration, coupling a second additional coil segment positioned within the additional cylinder to the longitudinal shaft such that as the longitudinal shaft rotates, the second additional coil segment is moved into the second additional area of concentration, producing a second additional voltage in the second additional coil segment as the plurality of flux forces within the second additional area of magnetic concentration are compressed, removing the second additional voltage from the second additional coil segment.

Additionally, there may be methods to produce DC mechanical power such as: a method of producing a radial motion of a shaft, the method characterized by: concentrating similarly polarized magnetic flux forces around a circumferential portion of a magnetic cylinder to create an area of magnetic concentration comprising a stacked plurality of similarly polarized magnetic flux forces, radially moving a coil segment into the area of magnetic concentration, applying a current to the coil segment to change the plurality of flux forces within the area of magnetic concentration, creating a repulsive magnetic force on the coil segment to move the coil segment out of the area of magnetic concentration, and cou-

21

pling the coil segment to a longitudinal shaft such that as the coil segment moves out of the area of concentration, the shaft rotates in a radial manner.

The methods of the above claims further characterized by: concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces wherein the additional area of magnetic concentration is radially positioned away from the area of magnetic concentration, radially moving an additional coil segment into the additional area of magnetic concentration, applying an additional current to the additional coil segment to change the plurality of flux forces within the additional area of magnetic concentration, creating an additional repulsive magnetic force on the additional coil segment to move the additional coil segment out of the additional area of concentration, and coupling the additional coil segment to the longitudinal shaft such that as the additional coil segment moves out of the additional area of concentration, the additional coil segment contributes to the radial shaft rotation.

The methods of the above claims further characterized by: concentrating similarly polarized magnetic flux forces around a circumferential portion of an additional magnetic cylinder positioned longitudinally away from the magnetic cylinder to create an additional area of magnetic concentration comprising an additional stacked plurality of similarly polarized magnetic flux forces, radially moving an additional coil segment into the additional area of magnetic concentration, applying an additional current to the additional coil segment to change the additional plurality of flux forces within the additional area of magnetic concentration, creating an additional repulsive magnetic force on the additional coil segment to move the additional coil segment out of the additional area of magnetic concentration, and coupling the additional coil segment to the longitudinal shaft such that as the additional coil segment moves out of the additional area of concentration, the additional coil segment contributes to the radial shaft rotation.

The methods of the above claims further characterized by: concentrating similarly polarized magnetic flux forces around an additional circumferential portion of the additional magnetic cylinder to create an second additional area of magnetic concentration comprising a second additional stacked plurality of similarly polarized magnetic flux forces wherein the second additional area of magnetic concentration is radially positioned away from the additional area of magnetic concentration, radially moving a second additional coil segment into the second additional area of magnetic concentration, applying a second additional current to the second additional coil segment to change the plurality of flux forces within the second additional area of magnetic concentration, creating a second additional repulsive magnetic force on the second additional coil segment to move the second additional coil segment out of the second additional area of concentration, and coupling the second additional coil segment to the longitudinal shaft such that as the second additional coil segment moves out of the second additional area of concentration, the second additional coil segment contributes to the radial shaft rotation.

As above, there may also be methods of creating the area of concentration: such as the methods of the above claims wherein the concentrating is further characterized by: positioning a longitudinal magnet within the magnetic cylinder, such that a longitudinal has a longitudinal axis that is parallel to a longitudinal axis of the shaft and that the poles of the longitudinal magnet are transverse to the longitudinal axis of

22

the shaft, positioning a first transverse magnet within the magnetic cylinder, such that the poles of the of the first transverse magnet are parallel to the longitudinal axis of the shaft, positioning a second transverse magnet within the magnetic cylinder, such that the poles of the of the second transverse magnet are parallel to the longitudinal axis of the shaft, such that similarly polarized magnet poles all face towards one area to produce the area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by: positioning a first magnet within the magnetic cylinder, positioning a second magnet within the magnetic cylinder, such that similarly polarized magnet poles of the first and second magnets face towards one area to produce the area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by positioning a third magnet within the magnetic cylinder, such that similarly polarized magnet poles of the first magnet, second magnet, and third magnet face towards one area to produce the area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by positioning a fourth magnet within the magnetic cylinder, such that similarly polarized magnet poles of the first magnet, second magnet, third magnet and fourth magnet face towards one area to produce the area of magnetic concentration.

The methods of the above claims further characterized by wherein the concentrating is further characterized by positioning a fifth magnet within the magnetic cylinder, such that similarly polarized magnet poles of the first magnet, second magnet, third magnet, fourth magnet and fifth magnets face towards one area to produce the area of magnetic concentration.

The methods of the above claims further characterized by wherein the concentrating is further characterized by positioning an additional magnets within the magnetic cylinder, such that similarly polarized magnetic poles of the first magnet and the polarized magnetic poles of the plurality of additional magnets face towards one area to produce the area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by positioning an electromagnetic magnet within the magnetic cylinder to produce the area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by: positioning a first magnet within the magnetic cylinder, positioning a second magnet within the magnetic cylinder, positioning an iron core between the first magnet and the second magnet, positioning conductive material around the iron core, and applying a current to the conductive material to produce an area of magnetic concentration.

The methods of the above claims wherein the concentrating is further characterized by positioning one or more iron cores or similar metals within the magnetic cylinder to assist in producing the area of magnetic concentration.

The abstract of the disclosure is provided for the sole reason of complying with the rules requiring an abstract, which will allow a searcher to quickly ascertain the subject matter of the technical disclosure of any patent issued from this disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

Any advantages and benefits described may not apply to all embodiments of the invention. When the word "means" is recited in a claim element, Applicant intends for the claim element to fall under 35 USC 112, paragraph 6. Often a label

23

of one or more words precedes the word “means”. The word or words preceding the word “means” is a label intended to ease referencing of claims elements and is not intended to convey a structural limitation. Such means-plus-function claims are intended to cover not only the structures described herein for performing the function and their structural equivalents, but also equivalent structures. For example, although a nail and a screw have different structures, they are equivalent structures since they both perform the function of fastening. Claims that do not use the word means are not intended to fall under 35 USC 112, paragraph 6.

The foregoing description of the embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many combinations, modifications and variations are possible in light of the above teaching. Undescribed embodiments which have interchanged components are still within the scope of the present invention. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

What is claimed is:

1. A system for generating electric voltage or mechanical power, the system comprising:

- a longitudinal shaft having a longitudinal axis,
- a partial toroidal magnetic cylinder having a center of curvature aligned with the longitudinal axis, the partial toroidal magnetic cylinder including:
 - a first magnetic longitudinal cylinder portion producing magnetic poles which are generally transversely and radially aligned with respect to the longitudinal axis,
 - a circumferential slot defined within and through the first magnetic longitudinal cylinder portion,
 - a second magnetic longitudinal cylinder portion producing magnetic poles which are generally transversely and radially aligned with respect to the longitudinal axis, the second magnetic longitudinal cylinder portion being positioned at a greater radial length from the longitudinal axis than the first magnetic longitudinal cylinder portion,
 - a first magnetic side ring portion producing magnetic poles which are generally aligned in parallel with the longitudinal axis and positioned adjacent to a first longitudinal end of the first magnetic longitudinal

24

cylinder portion and a first longitudinal end of the second magnetic longitudinal cylinder portion,

a second magnetic side ring portion producing magnetic poles which are generally aligned in parallel with the longitudinal axis and positioned adjacent to a longitudinal opposing end of the first magnetic longitudinal cylinder portion and a longitudinal opposing end of the second magnetic longitudinal cylinder portion, wherein the magnets poles of the partial toroidal magnetic cylinder are of the same polarity within the partial toroidal magnetic cylinder; a coil assembly including,

a circular core partially positioned radially between the first magnetic longitudinal cylinder portion and the second magnetic longitudinal cylinder portion and longitudinally between the first magnetic ring portion and the second magnetic ring portion,

a conductor wrapped around a portion of the circular core,

a hub coupling the circular core to the longitudinal shaft, a ring of magnet material coupled to the hub and radially positioned proximal to the circumferential slot to prevent magnetic flux forces from the magnetic poles of the first magnetic longitudinal cylinder, the second magnetic longitudinal cylinder, the first magnetic side ring portion, and the second magnetic side ring portion point from exiting the circumferential slot;

wherein similar or like magnetic poles of the first magnetic longitudinal cylinder, the second magnetic longitudinal cylinder, the first magnetic side ring portion, and the second magnetic side ring portion point towards the circular core, and

a housing sized to accommodate the circular core, the first side ring portion, the second magnetic side ring portion, and the first magnetic longitudinal cylinder and the second magnetic longitudinal cylinder.

2. The system of claim 1, further comprising at least one slip ring in electrical communication with the conductor to conduct electric current to or from the conductor.

3. The system of claim 1, further comprising at least two brushes in electrical communication with the conductor to conduct electric current to or from the conductor.

* * * * *